THE POTENTIAL OF THE SIERRA SAN PEDRO MARTIR AS A BIOSPHERE RESERVE.

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EXECUTIVE SUMMARY

Because of the characteristics described in this work, we consider that the Sierra San Pedro Mártir (SSPM) is worthy of being declared a biosphere reserve under UNESCO's Man and the Biosphere (MAB) Program. The range is covered by mixed conifer forests and shrublands of the Californian floristic province, which occur nowhere else in Mexico. The SSPM is unique within the Californian floristic province in that its majestic open forests and chaparral are still influenced by periodic ground fires. The area also hosts the largest single population of mountain sheep in Baja California, and an endemic fresh-water trout, as well as a number of rare and endemic species and subspecies of mammals, birds and plants. The Kiliwa, whose rancheria lies just north of the sierra, are one of the last remaining Indian cultures that still practice hunting and gathering in North America. The mission San Pedro Martir, a site of great historical importance, is found in the southern Sierra. The area's relative isolation has also preserved a traditional land use pattern of livestock grazing that dates aback to Dominican mission times early in the 19th century.

A biosphere reserve may also be an excellent institutional framework for protecting SSPM's environment and cultural heritage, as well as the scientific infrastructure of the National Astronomical Observatory. As a biosphere reserve, SSPM could serve to showcase research in fire ecology, with implications for similar ecosystems throughout the southwestern U.S. and northwestern Mexico. The biosphere reserve framework could also help in cooperative conservation efforts among the governments of Alta and Baja California toward the restoration of the magnificent California condor (*Gymnogyps califorianus*), which became locally extinct in SSPM during this century.

We recommend a SSPM biosphere reserve that includes a primary "core" in eastern Vallecitos to accommodate the need for strict control of land use and access for the National Observatory. This core should also include a campground, research station, and installations of federal and state agencies responsible for the environment. The mountain forest north of theVallecitos to Cerro Venado Blanco and Rancho Nuevo may also be included in the "core" for research purposes. A second "core" should be established to protect the lands of the Kiliwa, who are perilously close to vanishing. Buffer zones should include lands used seasonally for cattle grazing, mountain sheep (*Ovis canadensis cremnobates*), the Mission San PedroMártir, streams containing the endemic trout (*Oncorhynchus mykiss nelsonii*), and areas having rare or endemic plant and animal species. Ejido lands immediately surrounding the sierra could be placed under transition zones to accommodate their economic development.

Under the framework of the Mexican Modality in biosphere reserves, the establishment of a reserve requires the involvement and participation of the rural population. In SSPM, the rural population devotes itself mostly to cattle grazing, and so have an intimate and time-honored understanding of the natural environment of the sierra. Scientists, land users, and managers need to acquire a mutual understanding of the potential social, political and ecological conflicts of the region. Sustainable land use in SSPM will require the development of a database on the impacts of cattle grazing in relation to vegetation, wildland fire, and management of wildlife in a biosphere

reserve. Reintroduction of the condor may serve both as a focal rallying point for local populations and land managers, and as a managment centerpiece for the establishment of a biosphere reserve. Such an effort could bring international attention and require the integration of sustainable management of other natural resources.

The implementation of a biosphere reserve will require the establishment of a legal organization that assures the integration of the rural population with other groups and agencies working in the region. We propose the establishment of a civil organization that represents the interests of all parties to administer and operate the biosphere reserve.

INTRODUCTION

In 1986, the Directorate of Biosphere Reserves of the U.S. Man and the Biosphere Program (MAB) Program convened a binational selection panel to identify, evaluate, and select sites for nomination as biosphere reserves within the Californian Biogeographical Province (Barry, 1991). The sites selected were Parque Nacional San Pedro Mártir and Parque Nacional Constitucion de 1857 in Baja California, and Cuyamaca State Park, Palomar Mountain State Park, and Mount San Jacinto State Park (SJM) in Alta California. Later, a resolution recommending increased dialogue and cooperative efforts toward a Peninsular Range Transnational Reserve was passed by the Environmental Committee of the Commission of the Californias.

Quantitative studies on land use and vegetation dynamics, as well as the archaeology and cultural history of the Sierra San Pedro Mártir (SSPM) and SJM core areas were initiated during 1989-92 with funding received from US-MAB, NSF, CONACyT (Mexican National Council on Science and Technology) and the University of California UC MEXUS program. As part of the MAB grant, a symposium on "The Potential of the Peninsular Range of the Californias as a Biosphere Reserve" was held in Ensenada, Baja California in March, 1991 to promote discussion on the potential of the five parks as part of a cluster biosphere reserve (Franco Vizcaíno and Sosa Ramírez 1991).

After completion of preliminary research, the research team concluded that SSPM is worthy of biosphere status on its own merit. This range is covered by conifer forests and shrublands of the Californian floristic province, which occur nowhere else in Mexico (Wiggins 1960, 1980; Rzedowski 1978; Minnich 1987a). The SSPM is unique within the Californian floristic province in that its open and majestic forests and chaparral are still influenced by uncontrolled, periodic ground fires. Forests in Alta California have experienced fire suppression for almost 100 years. The SSPM also hosts the largest single population of bighorn sheep in Baja California as well as many endemic species, including a fresh-water trout. A biosphere reserve may also be an excellent institutional framework for the reintroduction of the historically extinct California Condor.

This region's remoteness has also preserved a rural landuse pattern that dates back to Dominican mission times early in the 19th century: cultivation of fruit trees and gardens near ranchsteads, and transhumance cattle grazing by families rooted to the region's open range livestock economy. Kiliwa Indians still practice hunting and gathering in the northern part of the range (Meigs 1935, 1939; Hinton and Owen 1957; Owen, 1963). This enduring land use gives SSPM a distinctive relationship between man and nature that is unique within the Californians. Furthermore, the SSPM has infrastructure compatible to a biosphere reserve. A forest reserve that includes SSPM --as well as the Sierra de Hansen and Mesa del Pinal in the Sierra Juárez-- was established in 1923 and the San Pedro Mártir National Park was created in 1947 (Gómez-Pompa and Dirzo 1994). The National Park was the first to be established in the Baja California peninsula. The sierra is also the site of the National University's Astronomical Observatory.

However, the trend for rapid economic development and population growth in Baja California

is sure to result in increasing utilization of the sierra. Hence, there will likely never be a more favorable opportunity to establish a biosphere reserve to protect the area's natural resources and land use system, as well as the existing scientific infrastructure.

The Biosphere Reserve Concept

In anticipation of the potential at the global and regional levels for exploitation of formerly inaccessible regions rich in biodiversity, the MAB program has developed a system of biosphere reserves with various aims, among them: sustainable use of natural resources, recuperation of species, and protection of habitat. An important aspect of the MAB program is to reconcile conservation and development by fostering scientific research. The Mexican model of Biosphere Reserves augments the original concept of conserving biodiversity, ecological research, and education, and training by incorporating regional socioeconomic problems as well as the participation of local populations and institutions in sharing the work of conservation (Halffter 1981; Gomez Pompa and Kaus 1992). As a result of the publication of the General Law on Ecological Equilibrium and Protection of the Environment of 1988, new decrees have declared the formation of more biosphere reserves (Reyes-Castillo 1991).

Our research to date provides evidence that SSPM's diverse biological resources is relatively unimpacted by existing landuse, and is worthy of biosphere reserve status.

CHARACTERISTICS OF THE REGION

The SSPM is a spectacular fault-bound range in the Peninsular Range geomorphic province (Gastil et al., 1975; O'Conner and Chase 1989), 100 km SE of Ensenada, Baja California, that extends southeastward from Valle Trinidad to 50 km west of San Felipe (Figs. 1 and 2). The range has three distinct terrain sectors: eastern escarpment, crest, and western flank. The eastern escarpment is greatly dissected with deep canyons and intervening cliff-straddled ridges. Relief is nearly vertical from the spine of the range (2,500 m) to the floor of the Sonoran Desert (alt., 500 m). The crest of the sierra is a broad plateau consisting of shallow alluvium-filled basins and extensive meadows with surface elevations increasing in three steps from 1,600 m at Arroyo Santa Eulalia in the south to 2,400 m at Vallecitos in the north. Higher ridges and local summits divide the crestal plateau from the eastern escarpment, with elevations ranging up to 3,100 m at Picacho del Diablo. The coastal flank is a steep, smooth, undissected fault escarpment with local relief of 300-600 m. To the west are rugged foothills and mesas, rimmed by the extensive plain of Valle San Telmo and by marine terraces along the coast.

Climate

The SSPM lies at the southern margin of the North American mediterranean climatic zone (Markham 1972; Reyes Coca et al 1990). Winter cyclones bring frontal rains with snow at higher elevations between November and April. Summer is mostly warm and dry, but afternoon thundershowers occur from July to September as the result of the North American monsoon. Average winter temperatures are mild, ranging from 10° C in coastal and desert valleys to 0° C

near the Observatory. In summer mean temperatures range from 25° C on the lower coastal slope to 15° at the Observatory and then rise to 30° C in the Sonoran Desert (Alvarez 1981; Reyes Coca et al 1990).

Long-term precipitation data are lacking in SSPM. Rancho Santa Cruz, the only weather station near the western slope, averages 310 mm yr^{-1}, with 90% of precipitation occurring in winter. In the Santa Clara Basin east of SPM, the average precipitation at several ranches ranges from 16-18 mm per year with 70% of precipitation occurring in summer.

In June, 1990, our research team erected a modest network of bulk precipitation gauges along an east-west and north-south axis across the sierra (Fig. 2) and obtained precipitation data bi-weekly in summer, and monthly to bi-monthly in winter. Our data (Table 1) shows that summer afternoon thundershowers produce 100-200 mm on the plateau. Amounts then decrease rapidly westward to <20 mm at Rancho Santa Cruz. During winter, orographic lift of frontal air masses from the Pacific ocean results in steadily increasing precipitation from 270 mm at Rancho Santa Cruz to 500-550 mm on the western and central plateau. Amounts decrease to 400 mm on the eastern and northern plateau due to rain shadows extending from the western rim. Total winter precipitation varied from 260-280 mm during the drought year of 1989-90 to 550-650 mm during the wet years of 1990-91 and 1991-92. The average annual precipitation is estimated to increase from 300 mm at the western base of SSPM to 600 mm on the western plateau and 500 mm on the northern and eastern plateaus. On the leeward eastern escarpment amounts decrease rapidly to ca. 250 mm at the desert floor.

Storm freezing levels, revealed by radiosonde data, show that the proportion of winter precipitation occurring as snow, increases from 15% at 1,700 m to 80% at 2,600 m (Minnich 1986). This was confirmed by snowpack measurements taken during 1991 and 1992 (Table 2) when snow depths varied from 30-90 cm and snow pack densities were 30-40% between December and March. This result is similar to those reported for the mountains of California (Miller 1955). High snow pack densities (heavy snow) reflect warm ambient temperatures (ca. 0° C) during winter storms. Snowpack water content varied from 70 to 350 mm. Snow was entirely melted by April or early May.

Vegetation

The vegetation of SSPM, interpreted from aerial photographs (after Minnich 1987a, 1988), shows the broad altitudinal zonation common to the Peninsular Ranges of southern California (Barbour 1988). Local patterning is modified by slope, aspect, and substrate. Chaparral on the lower western slope is replaced by mixed conifer forest on the summit plateau. This is followed on the eastern escarpment by pinyon forest on the higher elevations and Sonoran Desert scrub below 1,200 m. A generalized map of conifer forests is given in Fig. 3; common species are listed in Table 3.

The western flank of the SSPM below 1,800 m is mostly covered by chamise chaparral, which consists of contiguous, single-layered stands of interwoven, evergreen sclerophyllous shrubs

dominated by chamise (*Adenostoma fasciculatum*). Other common species are *Ceanothus greggii* and *Rhus ovata*. Minor shrubs and succulents include*Quercus cornelius-mulleri*, *Arctostaphylos glauca*, *Ceanothus leucodermis*, *Yucca schidigera*, and *Nolina palmeri*. Red shank chaparral (*Adenostoma sparsifolium*) is widespread in areas of granitic substrate. In the semi-arid basins near the base of the western escarpment, chamise grows extensively in open stands with *Juniperus californica* and desert shrubs including *Ephedra nevadensis*, *Simmondsia chinensis*, and *Yucca schidigera*.

Above 1,800 m, chamise chaparral gives place to peninsula manzanita chaparral (*Arctostaphylos peninsularis*) which extends to as high as 2,200-2,400 m on steep southern exposures. Chaparral associations grow on mostly steep slopes with infertile coarse-textured soils. Stands are fragmented into a patch mosaic of different age classes resulting from numerous burns.

In the chaparral zone, tree cover consists of hardwood forests restricted to streams, canyon floors, or margins of basins. Extensive riparian forests of *Populus fremontii* and *Salix* spp. follow the primary trunk streams of the western escarpment. *Platanus racemosa* occurs in small stands in the southwestern corner of the sierra. *Quercus agrifolia* grows near arroyos and along fault seeps at the base of the western escarpment between 1,000 and 1,800 m. On the lower west slope chaparral zone are short forests of the four-needle pinyon *P. quadrifolia*. This tree occurs in a highly fragmented patchwork of thousands of small stands. Two small colonies of *Pinus coulteri* are found near the northern and southern extremities of the range. This tree, which is noted for its enormous and partially serotinous cones, grows in dense *Arctostaphylos peninsularis* chaparral.

The semiarid eastern escarpment between 1,500 and 2,700 m is covered by more extensive short forests of *Pinus quadrifolia*. Below 1500 m, *P. quadrifolia* is replaced by another pinyon *P. monophylla*. Common shrubs in eastside pinyon forests include *Arctostaphylos peninsularis*, *Garrya grisea*, *Quercus chrysolepis*, *Q. cornelius-mulleri*, *Q. peninsularis*, *Rhus ovata*, *R. trilobata*, *Cercocarpus betuloides*, *Fremontodendron californicum*, and leaf-succulents such as *Yucca schidigera*, *Nolina parryi*, and *Agave deserti* (Chambers 1955; Wiggins 1944).

The eastern escarpment below 1,200 m is covered by Sonoran Desert microphyll woodlands and creosote bush scrub. Creosote bush scrub is dominated by the evergreen shrub *Larrea tridentata*, and drought-deciduous subshrubs, such as *Ambrosia dumosa* and *Encelia farinosa*. Important shrubs of microphyll woodland include *Olneya tesota*, *Cercidium floridum*, and *Dalea spinosa*. Both communities contain many stem and leaf succulents such as *Fouquieria splendens*, *Agave_deserti*, *A. moranii*, and a diversity of *Opuntia* spp. On the eastern escarpment of the southern Sierra San Pedro Mártir are numerous populations of *Brahea armata*, mostly near springs that seep from volcanic cap rock overlying granitic basement. This palm also extends westward to the coastal escarpment as far north as Arroyo San Pablo.

Undulations in the altitude of the crestal plateau of SPM result in variation in the species composition and distribution of mixed conifer forests. The lower plateaus between 1,500 and 2,100 m are covered by monotypic forests of *Pinus jeffreyi*, with most stands concentrated on

basin floors and the margins of meadows. Above 2,100 m, *P. jeffreyi* forest gives place to a zonal belt of floristically richer mixed conifer forests covering hillslopes as well as basin floors. This is similar to forests of California. Southern exposures are dominated by *P. jeffreyi* mixed with *Abies concolor* and *Pinus lambertiana*. *A. concolor* is dominant on northern exposures, but *Pinus lambertiana* is locally dominant on steep slopes and cliffs. The Baja California endemic *Cupressus montana* is frequently found in forests of *A. concolor* and *P. lambertiana* on the upper eastern escarpment. *Pinus contorta* is locally abundant in high meadows such as Vallecitos. *Calocedrus decurrens* is found along watercourses and some north-facing slopes, mostly on the western rim of the plateau. Among hardwood trees, *Populus tremuloides* establishes at wet sites above 2,400 m. *Quercus chrysolepis* forms an understory beneath mixed conifer forest on hilly areas of the plateau, as well as on steep north-facing exposures of the surrounding escarpments. *Q. peninsularis*, a Baja California endemic, grows extensively beneath *P. jeffreyi* forests south of La Grulla. Important shrubs in the understory of mixed conifer forests are *Arctostaphylos patula*, *A. pringlei*, *A. pungens*, *Ceanothus cordulatus*, *Artemisia tridentata*, *Salvia pachyphylla*, and *Symphoricarpos parishii*.

The forest belt contains numerous wet meadows that are the focal point of summer cattle grazing. Most meadows are relatively small, but in central SPM several (La Grulla, La Encantada, and Santa Rosa) each cover areas >500 ha. Dominant species include *Juncus* spp. and *Carex* spp., similar to meadows in the mountains of California. Other common herbs include *Poa annua*, *Ranunculus cymbalaria*, *Epilobium adenocaulon*, *Astragalus gruinus*, *Oenothera californica*, *Berula erecta*, and *Cirsium foliosum*. Drier or overgrazed meadows are covered by herbaceous perennials in such genera as *Achillea*, *Potentilla*, *Aster*, and *Muhlenbergia*.

SSPM is the last outpost of mediterranean climate in the Californian floristic province. Hence, nearly all tree species have their southern limits in the range (Minnich 1987a). Only *Quercus peninsularis*, *Pinus monophylla*, *Populus fremontii*, and *Brahea armata* extend farther south into the mountains of central and southern Baja California. *Abies concolor* and *P. tremuloides* occur farther south in the mountains of the Méxican Altiplano. Most chaparral species also have their southern limits in SSPM (Moran 1977; Wiggins 1980).

Surface hydrology, soil genesis, and fertility

Water budgets were estimated at three sites representative of the common plant communities in the SSPM (Fig. 2; Franco Vizcaíno 1991; Escoto Rodriguéz 1994): lower forest (La Puerta, 1,980 m), upper forest (La corona, 2,470 m), and wet meadow (Vallecitos, 2,380 m) during the period October 1989-October 1992. At these sites, precipitation was measured in bulk rain gauges, soil moisture was monitored with a neutron probe, deep drainage was estimated in mini-lysimeters, and runoff was estimated in small plots. Evapotranspiration (ET) was calculated for the 0-80 cm soil layer by difference, using the above variables in the general water-balance equation.

At the forest sites, soils are sandy and rock contact occurs at 60-80 cm, and so the profile has low water storage capacity (80-140 mm). Precipitation averaged 501 ± 17 in winter and 191 ±

100 mm in summer (n=3). Winter ET was about 40% of winter precipitation, while summer ET was about 125% of summer precipitation. Soils in the wet meadow are loamy and deep; water storage in the upper 150 cm is about 230 mm. Precipitation at Vallecitos averaged 386 ± 141 in winter, and 161 ± 22 mm in summer. But while winter ET was about 40% of winter precipitation, summer ET was about 200% of summer precipitation. These results indicate that forest and meadow vegetation utilize all the rain that falls during summer, but also require additional moisture stored in the soils during the previous winter. Overall, annual ET in the forest sites was 59 ± 21 percent of annual precipitation, but it was 87 ± 12 percent at Vallecitos.

At all three sites, some 60% of winter precipitation goes to runoff or deep drainage. Most of this moisture is released to streamflow lower in the watershed. The rest is stored in the soil profile and mobilized during summer. The amount carried over from winter to summer averages 40 mm at the forest sites, and about 300 mm in the wet meadows. Thus, shallow water tables must supply moisture to the vegetation in the meadows, particularly during wet years. After a wet winter (1993), the depth to the water table in late summer varied from 50-150 cm in the meadows at Vallecitos (Franco-Vizcaíno and Graham, unpublished data).

An important difference between the upper and lower forest sites is that the snowpack turns icy and the soil freezes at higher elevations. At the lower forest, snow melts quickly and meltwater percolates through the soil to produce significant deep drainage. At the upper forest, the snowpack remains for two to three months at a time, and meltwater apparently runs off over the frozen ground but beneath the snowpack. Thus, less water enters the soil profile during winter at the upper forest site, and there is consequently less deep drainage and less water stored in the soils than in the lower forest.

Soils at the three study sites (as well as those of the meadows and much of the SSPM forest) are derived from granites. They are sandy loams to loamy sands, and dark gray to dark gray brown. Examination of soil profiles at the forest sites revealed that these soils are moderately deep, well-drained, and show little profile development (*Typic Xeropsamments*). In the meadow, soils are deep (>150 cm), and appear to be influenced by a strong moisture gradient from the wet meadows to the slightly higher and drier meadow fringes and forests. The meadow soil, a loamy sand, showed moderate profile development and mottling (*Aeric Haplaquepts*). This mottling is consistent with an annual cycle of anaerobic conditions during winter and spring when soils are saturated, followed by drying and aerobic conditions during summer and fall. Schist is the only other major soil parent material in the SSPM. Examination of a soil that developed on schist, on a sloping forested site, revealed a moderately deep (50 cm), dark brown, well-drained, sandy loam having moderate profile development (*Typic Xerochrepts*).

Analysis of soil samples revealed that SSPM soils that are derived from granitoid rocks are moderately acid, non-saline, and infertile (Franco Vizcaíno, Sosa Ramírez and Graham, unpublished data). Concentrations of nitrogen, phosphorus, potassium, and magnesium in the soil solution were critically low, and lower than the minima reported for agricultural soils in Alta California (Franco Vizcaíno et al 1992).

Fire History

Recurrent fire is the most significant form of natural disturbance in northern Baja California. This is due to the region's mediterranean climate in which winter precipitation is followed by dry summers. Plant cover supported by winter precipitation is desiccated by summer drought, a condition that accentuates its flammable nature. Fire perimeter maps of SSPM (Fig. 4) show that most chaparral and forests on the west slope and plateau have burned at least once since 1925. Individual burns are as large as 8,000 ha, but most are less than 3,000 ha. This is similar to the pattern in the Sierra Juárez, which is located 80 km north of SPM (Minnich 1983, 1989). The average fire rotation period for all mixed conifer forest types in SSPM is estimated to be ca. 50-55 yr for chaparral and mixed conifer forests. Rotation periods in pinyon forests on the semiarid eastern escarpment are 100 to 200 years, or longer.

The tree-ring record of fire (Burk 1991) shows evidence of large regional fires during the 19th century. Large chaparral burns on the west slope spread onto the plateau at Vallecitos in 1862, 1899 and 1920, and at La Grulla in 1860, 1880, and 1923. The intervals between these burns is similar to those after 1925. However, a few trees at most sample sites also record others fires, perhaps local litter burns, or possibly lightning strikes.

After a lightning strike, flames alternately smolder in logs, snags, or root crown burls when the humidity is high, then spread through brush and forests in dry weather, persisting for weeks or months (Francisco Mayoral, personal comm.). As recently as 1989 two fires persisted for six weeks. Similar fire behavior was reported before fire control in the San Gabriel Mountains of southern California (Minnich 1987b).

Fire impacts on vegetation.

Chaparral

The high frequency of fires gives SSPM chaparral a complex patch structure, related to fire behavior and successional processes (Minnich 1983, 1989, Fig. 4). Due to the high fuel continuity of chaparral stands, fires are canopy burns (nearly all above-ground biomass is burned) and shrubs are even-aged in postfire succession. Previous fire history influences the spread to subsequent fires. During much of postfire succession, vegetation is resistant to fire. It is typical for fires in old stands to stop when they spread into younger ones, for lack of fuel. Thus, a high frequency of burns results in a fine patch structure, which helps to keep fires small.

Mixed conifer forest.

Analysis of aerial photos and ground-based sampling show that SPM mixed conifer forests are mostly open and park-like. They consist of mature trees with few pole-size trees and saplings, and open shrub cover (Passini et al 1989; Minnich and Barbour et al, in review,a). The surface fire regime also influences species composition because the different Californian mixed conifer forest trees respond differently to fire frequency and intensity (Barbour 1988, Rundel et al.,

1988). Fire intensities were high enough to cause significant mortality to pole-size and larger cohorts.

Examination of a series of aerial photographs taken between 1956 and 1991 revealed that measurable regeneration of trees occurs during postfire succession. On the other hand, the density of mature overstory trees showed no statistical change over time. This indicates climax-like, steady-state dynamics. The rate of tree progression from pole-size to overstory classes equals the rate of mortality within that overstory class, so density remains constant.

The open forest structure is also confirmed by field samples. Point quarter center transects revealed that mixed conifer forests consist of mostly old-growth trees. Stand densities ranged from 50 stems ha^{-1} in *Pinus jeffreyi* forest to 150 stems ha^{-1} in *Abies concolor* forest. Most forests have rather flat, multiple age structure but some have a classic climax-type inverse J-shaped distribution, with maximum stem density in the 0.7-1.0 m dbh. Sapling densities (stems < 3 cm dbh) average 160 ha^{-1}.

The open forest structure is likely caused by surfaces fires that selectively eliminate sapling and polesize trees in the understory, and yield stands of old-growth *Pinus jeffreyi* forests. The dominance of *P. jeffreyi* may be related in part to fire intensities which favor survival of this pine. *P. jeffreyi* bark is thicker and its canopy higher above ground fuels than those of *Abies concolor* and *Calocedrus decurrens*. Moreover, regeneration of *P. jeffreyi* is stimulated by ground fires that are intense enough to burn away litter and competing shrubs. But light ground fires inhibit regeneration of *A. concolor* and *C. decurrens*.

The SSPM forests have lower tree mortality rates from drought and bark beetle infestations than those in southern California (Savage 1994). Low mortality may be partly due to low tree density maintained by surface fires (Minnich et al, in review).

Fauna

The 1906 Biological Survey (Nelson 1921; Goldman 1916) produced the first general inventory of fauna of SSPM. Although this study is dated, these accounts are significant because they describe possible pre-historic distributions of many species and the subsequent decline of several due to hunting.

The vertebrate land fauna of SSPM is similar to that of California (Table 4). Common large mammals include mountain lions (*Felis concolor*), bobcats (*Felis rufus*), the Peninsular Range mountain sheep (*Ovis canadensis cremnbates*), coyotes (*Canis latrans*), badgers (*Taxidea taxus*), and foxes (*Urocyon cinereoargenteus*). Nelson (1921) reports the mountains were "swarmed" by rodents including jackrabbits (*Lepus*), cottontails (*Sylvilagus*), kangaroo rats (*Dipodomys merriami*), pocketmice (*Perognathus*), woodrats (*Neotoma lepida*), Beechy ground squirrel (*Spermophilus beecheyi*), and Douglas squirrel (*Tamiasciurus mearnsi*).

SSPM forests contain the typical insectivorous and fruit-eating resident birds found in

Californian forests, including the Mountain Chickadee (*Parus gambeli*), juncos (*Junco* spp.), nuthatches (*Sitta* spp.), and several woodpeckers (*Picoides, Melanerpes*) (Table 5). Common birds of the chaparral are the wren tit (*Chamaea fasiata*), brown towhee (*Pipilo fuscus*), scrub jay (*Aphelocoma coerulescens*, California quail (*Callipepla californica*), and California thrasher (*Toxostoma redivivum*).

The reptilian fauna listed by Nelson (1921) is indistinguishable from that of California. The similarity of reptiles is hypothesized in relation migration routes into the geographically isolated peninsula from the north, as with other terrestrial lifeforms. Reptile species diversity is much greater in the Sonoran Desert and coastal foothills than in the cold climates of SPM. Lizards and snakes inhabit mixed conifer forests; frogs are also found at wet sites.

It is hypothesized (Nelson, 1921) that fauna, as well as other terrestrial lifeforms, migrated into the geographically isolated peninsula from the north. Still, there are subtle differences in the biota between SSPM and the mountains of California. For example, the Steller Jay (*Cyanocitta stelleri*) and the Clark's nutcracker (*Nucifraga columbiana*), both common in California forests, are seldom observed and apparently do not breed in forests on the Mexican side (Kratter 1991, 1992). The pinyon jay (*Gymnorhinus cyanocephalus*), which normally occupies pinyon forests and high deserts in California, has an expanded its range into mixed conifer forests and subalpine *Pinus contorta* forests in SSPM. Among mammals, a tree squirrel (*Tamiasciurus mearnsi*), which is a species endemic to SSPM (Mellink Bijtel 1991), and a close relative to the Kaibab squirrel of northern Arizona, replaces the California Gray Squirrel (*Sciurus griseus*) which occurs in Alta California. A bat (*Myotis milleri*) is also considered an endemic species (Mellink Bijetl 1991). In addition, five subspecies of mammals, and 18 of resident birds, are considered endemic to the region (Tables 4-5, Mellink Bijtel 1991, Grinnell 1928). The phenotypic differentiation of these species and subspecies suggests a lengthy period of isolation without gene flow from outside populations (Kratter 1991, 1992).

Annotated species lists of reptiles, insects, birds, heteromyid rodents, and bats of Baja California have been examined for Simpson's (1964) "peninsular effect," which predicts that species diversity (density) increases from the tip of a Peninsula to its connecting point with the primary land mass (Taylor and Plannmuller 1978). But recent studies show that species richness is not due so much to the isolating effects of a peninsula as they are to present habitat and vegetation distributions, which are functions of the immigration/extinction equilibrium (Brown 1987). The northern part of Baja California, including SSPM, tends to have greater species diversity in all these groups than other parts of the peninsula probably because of the region's mesic habitats and heavy vegetation cover.

Rare and Endangered Species

Plants (Table 6)

The best-known endemic of SSPM is *Cupressus montana*, which covers an area of only 2,400 ha. Although populations have been long known from the ledges and fractures on Picacho del

Diablo, we discovered new populations in color aerial photographs taken in 1991 of the eastern escarpment near Cerro Venado Blanco, and in pinyon forests between this area and Picacho del Diablo, and southward along the escarpment to Arroyo El Cajon. On the plateau, a few populations of *C. montana* occur along arroyos leading into La Encantada meadow. *Garrya grisea*, the only shrub endemic to SSPM, is common in mixed conifer forest. *Agave moranii* is found only in the lower eastern escarpment and adjoining bajadas.

Two shrubs are very rare in SSPM. The only known occurrence of *Rhus kearneyi* is from Cañon del Diablo. This species is known elsewhere only from the Tinajas Altas of Sonora and in the higher ranges of the Central Desert to as far south as Volcán las Tres Virgenes (Moran, 1983). *Cercocarpus ledifolius* is widespread in the western United States. However, its known distribution in northern Baja California (and México) is a single summit east of the National Observatory (ca. 30 ha.).

All other endemic plants are annuals or herbaceous perennials; many are restricted to meadows and are thus subject to livestock grazing: *Haplopappus wigginsii*, *Lesquerella peninsularis*, *Senecio martirensis*, *Mimulus purpureus pauxillus*, *Ophiocephalus angustifolius*, *Astragalus gruinus*, and *Trifolium wigginsii*. The latter two species are abundant at the Vallecitos meadows and appear to tolerate heavy grazing. Several endemics are restricted to steep, rocky slopes and crevices, especially on the high eastern escarpment. These include *Haplopappus martirensis*, *H. pulvinatus*, *Heterotheca martirensis*, *Stephenomeria monocephala*, *Hedeoma martirense*, and *Sphaeralcia martirense*. Other endemics occur in sandy soils and granite boulders of the forested plateau: *Eriogonum hastatum*, *Hemizonia martirensis*, *Draba corrugata*, *Galium wigginsii*, and *G. diabloense*.

Fish

Fresh water fish are nearly absent from SSPM because permanent streams are scarce. However, several arroyos contain an endemic rainbow trout (*Oncorhynchus mykiss Nelsonii*) that tolerates the warm water (27° C) in standing pools of arroyos during periods of very low runoff. Apparently, the trout was originally found in the San Antonio branch of the Rio Santo Domingo, but has since been planted to other streams, such as Rio San Rafael (Henderson, 1960). This fish is characterized by a selective trophic strategy with prey size in which diet shifts with the seasonal availability of resources (Ruiz-Campos 1989; Ruiz-Campos and Cota-Serrano 1992). Changes in diet occurred among all size classes year round. The species recruits in May-June and cohorts reach maturity the following winter.

Megafauna

By the time of the 1906 Biological Survey, hunting had already contributed to the decline or extinction of several big game animals in Baja California, similar to the situation in California. However, conservation practices in recent decades have helped protect other species. The pronghorn antelope (*Antilocapra americana*) once occupied large areas of the peninsula, but has since been extirpated (Brown 1992). The last report of this species in adjoining San Diego

County was in 1921 (Bond 1977). The mountain sheep (*Ovis canadensis cremnobates*) once occupied most of the ranges on the eastern half of the peninsula, but was hunted for sport or slaughtered to supply mining camps and small towns with meat (Nelson 1921; Mellink Bijtel 1993). Still, as many as 1,000-2,000 animals survive on the remote eastern escarpment of SSPM (Aguilar-Rodríguez 1991). Nelson (1921) states that mule deer had become more scarce by the turn of the century. Presently that animal is fully protected from hunting within the National Park and is common in SSPM forests.

The Grizzly Bear (*Ursus horribilis*) was reported as far south as the Sierra Juárez, but it was apparently not native to SSPM (Nelson 1921). There are no reliable records of wolves on the peninsula, although Nelson (1921) indicates they must have been native. Spanish explorers of the 18th century did not refer to wolves during their explorations (Minnich and Franco, in review). The mountain lion (*Felis concolor*) is native to SPM (Henderson 1960). During their expeditions through SSPM, both Linck (1766) and Serra (1769) reported that mountain lions had made their livestock restless on several nights (Minnich and Franco Vizcaíno, in review). We have commonly seen tracks in the sierra .

The California Condor *(Gymnogyps californianus*) was native to the sierra, and it was observed or collected many times after 1879 (Wilber and Kiff, 1980), including the biological survey (Nelson, 1921). The SSPM was the most favorable habitat for this bird in northern Baja California because of the abundance of meadows, occurrance of native ungulates such as bighorn sheep and deer, the seasonal large numbers of cattle, and the presence of favorable nesting sites. The condors of northern Baja California were probably an isolated population since the late 19th century because condors in adjacent areas had already disappeared by then (Wilber and Kiff, 1980). The condor may have had an annual nesting cycle similar to that of the California population. Condors probably nested in the coastal ranges with less rigorous climate in winter, and the nonbreeding birds moved to summer feeding and roosting areas at higher elevations. Although it was reported to be in the range as late as the 1930s, it is now extinct (Koford 1953, Henderson 1960, 1964; Robinson 1975; Wilber and Kiff 1980). The demise of the condor is attributed to prolonged drought and shortages in domestic and native ungulates following overgrazing in the 1920s (Koford, 1953). Its extermination was also attributed due to slaughter for sport and use of its quill feathers as gold-dust receptacles (Henderson 1960).

HISTORY AND LAND USE OF SPM

Although the SSPM was first observed from a distance during sea voyages to the northern Gulf of California by Ulloa (1539) and the Jesuit fathers Eusebio Francisco Kino and Jaun Maria Salvatierra (1701), the sierra was first explored and settled during a relatively brief period during a turbulent time in California mission history in the late 18th century (Meigs 1935). Jesuit control of the peninsula was abruptly terminated by their expulsion in 1767. They were replaced by Franciscan and Dominican missionaries. The Spanish crown was also intent on expanding its sphere of influence northward from the deserts of Baja California to Alta California, to deflect the threat of foreign encroachment.

The first European to visit the region was the Jesuit Wenceslaus Linck, minister of the San Borja mission in central Baja California (Burrus 1966; Meigs 1935). In 1766, Linck crossed the southern SSPM and explored the deserts east of the range. After the Jesuits left in 1768, the region was turned over to the Franciscan order which organized a historic expedition across northern Baja California to San Diego. This journey was part of an effort to resist encroachment of the Russians, who were extending their settlements from Alaska down the Pacific coast (Bolton 1927). The Franciscans traversed the western margin of SPM in 1769 (Bolton 1927:6; Meigs (1935:11). Subsequent explorations of the sierra by Longinos Martínez (1792) and Arrillaga (1796) were undertaken when the Dominicans established the Mission San Pedro Mártir de Verona (Minnich and Franco, in review).

The Kiliwa Indians and Mission San Pedro Mártir de Verona.

When northern Baja California came under Dominican control, the friars first established missions along the coast, then expanded the frontier to the inland mountains (Meigs 1935; Tiscareno and Robinson 1969). In 1794 the Dominicans established the mission San Pedro Mártir de Verona at a "watered forest-rimmed meadow," named Casilepe. A recent discovery of foundation stones indicates this site was the north end of La Grulla meadow (Foster, 1992). Casilepe proved to be unsuitable due to the severity of climate. Soon after, the Dominicans selected a final, more temperate site at lower altitudes (1,550 m) along Arroyo El Horno, 10 km east of San Isidoro (Fig. 2).

The prehistoric Kiliwa, who resisted missionization efforts of the Dominicans, have been placed by anthropologists into the Yuman linguistic group (Meigs 1935, 1939). They were nomadic hunters and gatherers who utilized much of SSPM, but practiced no agriculture (Meigs 1939; Owen 1963). The Kiliwa still survive along the northwestern flanks of the sierra. (The related Paipai also survive in the adjoining southern Sierra Juárez.) Hinton (1957) estimates that living Kiliwa in SSPM are in three rancherías numbering 60 people, with most inhabitants along Arroyo León, an area they consider as their "reserve" set up by the government. They still practice hunting and gathering as late as the first decades of this century (Meigs 1939). One of us (RAM) has observed trails leading away from settlements into the surrounding vegetation in the late 1960s. The principal food is mescal (*Agave* spp., *Yucca* spp.) and mescal roasting is practiced in the northwestern basins of SSPM. The high country of SSPM proper is utilized for the harvest or hunting of pinyon nuts, acorns, deer, rabbits, and other resources. Corn and squash are cultivated in a few plots. Some Kiliwa also work as cowboys for surrounding ejidos (Hinton 1957). According to Kiliwa informants, the forested plateau of SSPM was never permanently inhabited by Indians because of the winter cold (Meigs 1935, 1939).

The mission San Pedro Mártir de Verona was short-lived (1794-1806), but was unique among the new world missions because it was devoted to livestock grazing instead of agriculture (Foster 1991). The mission was of typical Dominican design, consisting of a series of adobe buildings, some with stone cobble foundations. These were connected by a perimeter wall that protected the inhabitants during periods of unrest. Written records relating to the mission are scant. Arrillaga reported the mission sent cattle to La Encantada meadow for summer grazing. Cattle

were also grazed at the other major meadows (Meigs 1935). The population at the mission was modest, numbering only 94 in the year 1801. Few Indians were available for the mission since much of the area was without permanent rancherías. The mission managed several crops of wheat, corn and beans, irrigated by ditches from two permanent springs.

The Dominicans endured a troubled existence, as hostile Indians often raided the outposts, killing men and driving out cattle. Indians were also decimated by disease. The mission was closed in 1806, having operated only 12 years. Indeed, the survival of the Kiliwa was no doubt related to the rapid failure of Dominican mission efforts in SSPM.

Livestock Grazing and Mining

The SSPM is used for summer pasture since the establishment of mission San Pedro Mártir two centuries ago (Henderson 1960, 1964; Meling-Pompa 1991a,b). After the mission period, Dominican land holdings were granted or sold to local citizens, usually Mexican Government officials and military officers. They began subsistence cattle ranching in the sierra, mostly in open range. The gold strikes at Real del Castillo (1872) and El Alamo (1889) in the Sierra Juárez, and at El Socorro and Valladares (1874) on the west base of the Sierra San Pedro Mártir, encouraged larger cattle herds and commercialization of operations.

The rich Socorro placers on the west slope of SSPM were the scene of a large-scale hydraulic mining operation. During the 1906 Biological Survey, Nelson (1921) described a "large ditch" and "a well made trail" on the northern escarpment of SPM whose function was to divert waters of the Rio San Rafael to the El Socorro placers. The ditch, which spanned a length of 18 miles (30 km), was constructed in 1893 by Harry Johnson, a resourceful miner from Texas. The tailings from this strike may still be seen today at El Socorro (Fig. 2). The Johnson ranch was burned by rebels during the revolution in 1911. Salvador Meling, who immigrated to northern Baja California from Norway, helped to repair the ranch and married into the Johnson family in 1913. The Meling family now operates Rancho San José, a cattle and guest ranch in the foothills of the western SSPM (Robinson 1975). By the end of the 19th century, gold was being mined mostly from placers along the west edge of SSPM at such camps as Socorro, Valladares, Buena Vista, and Las Chollas. Political and economic disruptions during the early Mexican Revolution suspended mining, but thereafter placers were reworked from 1920-1940 (Henderson, 1960).

Open-range cattle grazing in SSPM has continued unaltered to this day, and largely under control of the same families. A comprehensive list of cattlemen operating from Valle San Telmo and Santo Domingo and used SSPM lands from 1828 to 1915 was compiled and discussed by Meling-Pompa (1991a,b). Francisco Mayoral, a SARH employee at the Parque Nacional San Pedro Mártir since the 1940s, also made reference to that list during an interview in 1990. Cattlemen of the early 19th century were the ancestors of the cattlemen who now live in the region.

Grazing of sheep in Baja California began ca. 1910, when it was prohibited from southern California mountain pastures by the newly developed system of National Forests. American

investors organized sheep drives, under Basque shepherds, that began in August near Tijuana and returned from as far south as SSPM in October. According to Meling Pompa (1991a,b), sheep were abundant in SPM between 1911 and 1964, after which they were prohibited from the sierra. However, Mayoral (pers. comm.) indicated that sheep still entered the sierra as late as 1975.

Present Land Use and Land Ownership

SSPM lands are primarily divided between the National Park and ejido lands. The eastern escarpment is essentially not utilized. The National Park covers ca. 60,000 ha that includes most of the north and central plateau from Cerro Venado Blanco in the north through the meadows at Vallecitos, La Grulla, and La Encantada in the south (Fig. 2). Moving clockwise, the park boundaries are circumscribed by 8 localities: 1) 31° 05'N, 115° 35'W; 2) 31° 05', 115° 27'; 3) 31° 00, 115°22 1/2'(Picacho del Diablo); 4) 30° 57', 115° 18'; 5) 30° 56 1/2, 115° 16'; 6) 30° 52 1/2, 115° 17 1/2'; 7) 30° 49', 115° 30 1/2'; 8) 30° 58, 115° 38', then back to point (1). The forest reserve covers a larger area that includes both national park and ejido lands. The reserve boundaries are bounded by the 1,000 m contour and includes the entire SSPM from Valle Trinidad south to lat. 30°, as well as some mesas and foothills to the west of the range.

Cattle operations in the Bramadero ejido are under control of 20 to 30 commercial owners. The ejido, which covers an area of 300,000 ha, mostly on the west slope of SSPM, is based near Sinaloa in the center of Valle San Telmo (Fig. 1); it includes a number of dispersed satellite ranches at the west base of SPM: Santa Cruz, El Potrero, San Antonio, La Concepción, Valladares, and La Suerte. The primary access of La Suerte to the coast is along a road farther south to near Lázaro Cárdenas. Most satellite ranches are located near permanent streams and have developed rustic diversion systems to irrigate small areas of fruit trees and grain crops. Two other settlements, Rancho San José (Meling Ranch) and San Rafael (Mike's Sky Rancho), graze cattle but are also managed as tourist "guest ranches" (Robinson, 1975).

According to Meling Pompa (1991a,b), the present cattle grazing economy is much like that practiced from 1828 to 1915. The SSPM are used exclusively for summer pasture; this resource provides 50-75% of the potential for cattle production in the ejidos. Cattle can survive winter better in lowlands if they have been fed well in the mountain the previous summer. During the winter rainy season, cattle graze on annual herbaceous cover and feed on crops in the agricultural zones in the basin of San Telmo and along Arroyo Santo Domingo basin. Once the wildland vegetation has cured, cattle are driven into the mountain meadows during May and June, depending on rainfall the previous winter. In late spring, cattle are rounded up and bathed, vaccinated, deparasitized, branded, and marked. Afterwards, they are herded up into the mountains in drives that last 3 to 10 days. In dry years cattle are hauled up by truck.

The primary pasture on the SSPM plateau are the large meadows of La Grulla, La Encantada, Santo Tomás, and Santa Rosa, and Vallecitos. The meadows in the vicinity of Cerro Venado Blanco at the northern end of SPM are too small to justify bringing cattle there. In 1987, after a wet winter, we found these small meadows to be almost untouched by livestock. However, they were heavily grazed during the drought of 1988-1990.

Cattle drives follow four primary trails: 1) Rancho Santa Cruz eastward to La Grulla and La Encantada meadows; 2) Rancho El Coyote to the north end of Sierra Corona at Corral de Sam; 3) Rancho San Isidoro (abandoned) to Mission San Pedro Mártir and Santa Rosa Meadow; and 4) La Suerte to Arroyo Santa Eulalia in southern SSPM. Meling-Pompa (1991a,b) indicated that cattle must be watched constantly while they are in the park and they are frequently moved to better pasture. The cattle remain until late October when intense cold begins; they are then rounded up, and driven downwards along the same trails to the same ranches from which they came. The cattle seem to know the mountain and follow the trails without having to be driven.

The cattlemen claim that sheep undermined the cattle grazing economy due to the divergent management practices of sheepmen and cattlemen (Meling-Pompa (1991a). They say that because sheep bite to ground level and were grazed in large flocks that were moved only when pastures were consumed. Grazing of sheep in flocks up to 2,000 head resulted in damage to plant roots and removal of young trees, and herbaceous cover. Cattle are grazed in dispersed manner and they do little damage to plant roots and young pines. Mayoral (pers. comm.) indicates that a grazing tax was placed upon cattlemen during the 1960s and 1970s in response to overgrazing. However it proved to be unenforceable and by 1975 grazing remained uncontrolled, as there were as many as 4,000-5,000 cattle and 10,000 sheep.

Transportation

Until the mid-20th century, the SSPM was accessible only by foot or horseback, mostly along the trails used to drive cattle between the mountain meadows since Dominican mission times. The area was accessible from the east via ancient Indian paths along Cañadas El Cajon, Huatamote, and Agua Caliente (Robinson, 1975). In 1949, a primitive road was constructed from Rancho San Rafael to Corral de Sam in the northwest corner of the plateau. Another was established from Rancho San José to the present site of SARH facilities at La Puerta. These roads were constructed ostensibly to exploit the timber on the plateau, but logging was prohibited by the National Park before sawmills could be established (Henderson 1964). An improved graded road was built in 1968 to support the National Observatory; it paralleled the old Meling road to La Puerta, then wound through Vallecitos to the telescopes. This road is now the primary access to the sierra. Secondary roads were built north from the main road along Sierra Corona and from Campo Forestal to the upper reaches of Arroyo San Rafael, and south to Cerro Botella Azul and La Tasajera. Slopes north of Arroyo San Rafael and the southern half of the range, including the pastures of La Grulla and La Encantada, and the mission are still inaccessible by motor vehicles.

The Observatorio Astronómico Nacional de San Pedro Mártir

Analysis of meteorological satellite imagery revealed that the northern part of Baja California is one of the three least cloudy regions in the world (Mendoza et al. 1972). Beginning in 1967, the Mexican National University (UNAM) built a series of telescopes on a 2,800 m summit (lat. 31° 02' 30" N, long. 115° 27'30"W) which comprise the National Observatory (Mendoza et al 1972; Alvarez and Maisterrena 1977; Alvarez 1981; Tapia 1992). The observatory is supported by nearby maintenance facilities and living quarters. Radio towers have been located on both the

western and eastern rims of the plateau for radio communications between UNAM personnel and their headquarters in Ensenada, as well as with SARH employees, and other agencies off the sierra. The primary road is annually maintained to support biweekly transportation of astronomy staff and researchers to and from the Observatory and UNAM headquarters.

Agriculture in the eastern basins

Commercial irrigated agriculture has been implemented in scattered localities in the desert basins east of SSPM. These include Santa Clara in Valle Santa Clara, and the settlements of Ejido Plan Nacional Agrario, El Chaparral, Rancho Algodón, and Agua Caliente in Valle Chico. The precipitous eastern escarpment of SPM virtually isolates these ranches from activities of the sierra.

Population

Available census data (Estados Unidos Mexicanos, 1983) is too generalized to determine population characteristics specific to SSPM. Hence, it is only possible to estimate the local population on the assumption that most ranches comprise a few families. Since there exist in the immediate vicinity of SSPM only 5 major ranches on the west side of SPM and 4 ranches on the east side, we estimate that the total population of the region is several hundred. Some smaller ranches appear to be abandoned. With the exception of personnel at the National Observatory, the SSPM plateau proper has no permanent inhabitants.

The nearest village-scale population center is Ejido Sinaloa (Bramadero) in the center of Valle San Telmo, as well as the mission village of San Telmo, 15 km west. Both settlements number perhaps 500. Along the coastal highway, a number of villages and towns have grown rapidly in association with extensive commercial tomato plantations. They include Colonet, Lic. Gustavo Díaz Ordaz, Rubén Jaramillo, Camalú, Colonia Vicente Guerrero, Lázaro Cárdenas, and San Quintín (Fig. 1). Another large population center of Valle Trinidad lies to the north. This basin is noted for irrigation agriculture, dry farming of grains, and fruit horticulture. The SSPM was formerly accessible from Valle Trinidad via a road between Rancho San Rafael and San José, but this section was destroyed by floods in 1979 and 1980.

CONFLICTS FOR THE BIOSPHERE RESERVE

The SSPM meadows have been used for summer pasture since the establishment of the Dominican mission system in the late 18th century. Hence, under the framework of the Mexican Modality, establishment of a biosphere reserve will require the incorporation of a grazing economy. The rural population has a long-term understanding of the natural environment of the sierra, including virtually every ecological issue of a reserve addressed in this report. The creation of a reserve will require that scientists, land users, and managers acquire a mutual understanding of the potential social, political and ecological conflicts of the region. Sustainable land use in SPM will require the development of a database on the impacts of cattle grazing in relation to vegetation, wildland fire, and management of wildlife in a biosphere reserve. Unfortunately,

tensions have emerged in the past between land users and managers on these impacts, in part because scientific data on the effects of cattle grazing are lacking.

For the past decades, SARH (pers. comm. F.Mayoral) attempted to regulate livestock numbers within the carrying capacities in the major meadows. Conversely, the cattlemen have attempted to improve the range condition of the National Park. There was also an attempt by cattlemen to create an association for the conservation of SPM, but the petition was "denied by the authorities" (Meling Pompa 1991a). However, an agreement was established between cattlemen and SARH whereby cattlemen would participate directly in the infrastructure works necessary to bring about controlled exploitation of the pastoral resource, such as fencing of pastures and corrals, watering troughs, reseeding meadows, and control of soil erosion. Cattlemen have also cooperated with forest authorities in fighting fires, feeding personnel, and providing beasts of burden. The principal meadows (La Encantada, La Grulla, Santa Rosa, Santo Tomás, Vallecitos) have been partitioned by the ejidos.

Impacts of cattle grazing

The entire SSPM is exposed to some degree of grazing because stray cattle wander from the primary herds in the meadows, usually along trails connecting the meadows (Meling Pompa 1991). The intensity of grazing ranges from modest in northern SSPM, where meadows are small, to intense in areas surrounding the larger meadows of Vallecitos, La Grulla, and La Encantada to the south. Horses are important in some fenced areas. Cattle exclosure experiments at our lower forest, upper forest and meadow sites have provided preliminary data on carrying capacities that may help reconcile difficulties between ejidatarios and SARH (Barbour et al, unpublished data). More research will no doubt be necessary.

Forests

Data obtained in small areas fenced to exclude cattle suggest that cattle grazing in forests has no measurable effect on herbaceous and shrub cover. Neither did cattle impact the recruitment of conifers. Sapling counts at the Sierra Corona horse meadow and at an 8 yr old government exclosure (COTECOCA) at Vallecitos failed to show consistent differences in sapling densities inside and outside their perimeter fences. Sapling densities 2-3 times greater than overstory trees in 25 forest samples is a further indication that livestock grazing does not significantly affect regeneration of forests.

In field observations in SSPM and in the Sierra Juárez, we found that most shrub species in the chaparral and mixed conifer forest were unpalatable to livestock (Minnich and Bahre, 1995; Freedman, 1984). When meadow forage was scarce during the drought of 1988-90, we found cattle skeletons in areas with permanent water (they did not die of thirst), indicating livestock would avoid shrubs even when herbaceous cover is scarce.

Meadows

Our best quantitiative information comes from Vallecitos. As shown in Table 7, cover and biomass were low in both exclosures and controls during the drought years of 1989 and 1990. However, only one year of cattle exclusion during the drought had a significant effect on both cover and biomass (1990 data show 60% more cover and 50% more biomass in exclosures vs controls). During years of normal or above-normal precipitation (1991, 1992, 1993), biomass increased by an order of magnitude both inside and outside of exclosures, but again biomass was greater in cattle exclosures by an average of 50%. Plant cover was also 14% greater in cattle exclosures during those years. Thus, the higher biomass inside exclosures was due to plants being taller.

Some 116 flowering plant species occur in Vallecitos meadow, but only about a dozen low-growing herbaceous perennials contribute significant cover and biomass: *Aster occidentalis*, *Eleocharis pauciflora*, *Muhlenbergia richardsonis*, *Trifolium wigginsii* (a SPM endemic), *Potentilla wheeleri*, and several species of *Juncus* and *Carex*. We have noticed large fluctuations in the frequency of some of these species from year to year, but these variations appear to reflect annual and seasonal amounts of precipitation far more than they reflect grazing pressure. In our exclosures, four years of cattle exclusion have had no effect on species composition.

Excluding cattle for longer periods appears to favor the establishment of native bunch grasses. We were able to study an abandoned COTECOCA exclosure constructed in 1984 to determine carrying capacity. The dominant species in this exclosure are several bunch grasses (*Koeleria cristata*, *Poa berlandieri*, *Sitanion hystrix*, and *Stipa* spp.), in contrast to forb dominance throughout the grazed portion of the meadow. Biomass within this exclosure, measured 8 years after cattle had been excluded was more than twice the biomass in our 4 year-old exclosures that same season.

Research that utilizes the relationship between cattle production and plant growth shows that, in most cases, cattle production can be increased while still moving toward sustainability, typically through a pasture rotation system. This is accomplished by rotating cattle from area to area, leaving enough biomass to permit the maximum possible recuperation of the vegetation. If unmanaged cattle tend to keep the highest quality forage cropped closer to the ground than lower quality forage. The result is that low quality, undesirable plants have the advantage during the growing season. Using grazing trials in controlled conditions, researchers can determine the optimum amount of standing biomass to leave to maximize beef production without long-term negative effects of overgrazing.

We can conclude that moderately grazed wet meadows, such as Vallecitos the meadows have been degraded to some extent in cover, biomass, and species diversity by cattle grazing. However, the rapid build-up in biomass after normal rains returned in 1991 shows that meadow species are very resilient. The COTECOCA plot also demonstrates that palatable perennial bunch grasses may also come back within a decade. Resilience was not characteristic for all meadows, and certainly not for dry meadows such as portions of La Grulla and La Encantada.

Wildland fire

Tensions also exist between SARH foresters and ranchers concerning wildland fire. In Baja California both federal and state agencies responsible for forest management have been all too eager to adopt fire suppression policies without recognizing that attempts to protect forests from fire will be counter-productive. In mediterranean regions fire has long been used by cattlemen as a management tool to set back vegetation from advanced successional states, to more open early seral stages that have herbaceous forage (Minnich et al, 1993). According to Meling Pompa (1991a,b), SSPM ranchers recognize that fire has always been present in the sierra, and have deliberately burned chaparral and meadows to improve access and forage. However, fire protection has been emphasized in recent years and SARH foresters have even enlisted the aid of ranchers in fire fighting.

Fire control will be counter-productive because fire plays a crucial role in chaparral and forest structure and dynamics (Wright and Bailey 1982, Heinselman 1981a,b, Kilgore 1981). For example, fire suppression in the United State side since 1900-25 has resulted in much larger and more intense fires than in Baja California. In chaparral, the interval between fires is more influenced by successional processes than ignition rates, as mostly old-growth stands are burned. In SSPM, numerous small fire events tend to fragment stands into a fine mixture of age classes, a process which appears to help preclude large fires. Fire suppression in California results in the homogenization of the stand mosaic, and stimulates ever-larger fires. Furthermore, fire control selects for uncontrolled fires to escape in severest weather, leading to higher fire magnitudes, and more complete chaparral denudation (Minnich 1983, 1989, Minnich and Chou, in review).

Experience with fire suppression in California indicates that controlling fires in SSPM is likely to result in build-up of fuel and thicker, closer stands. In the San Bernardino Mountains of southern California, nearly 100 years of suppression has caused stand densities to increase from 100 stems ha^{-1} in 1932 to 200-300 stems ha^{-1} in 1992. Densities are locally as high as 500 stems ha^{-1} (Minnich et al, in review). Likewise, forests in the Sierra Nevada average 500 stems ha^{-1} (Vankat 1970; Vankat and Major 1978; McKelvey and Johnston 1992). Forests in California also show an age-specific trend in which juvenile, pole-size cohorts of such forests are heavily dominated by *Abies concolor* and *Calocedrus decurrens*, whereas mature, overstory cohorts are dominated by *Pinus ponderosa* and *P. jeffreyi* (Rundel et al 1988; Barbour 1988; MeKelvey and Johnston 1992; Minnich et al. 1995). Stand thickening and fuel build-up has also led to enormous canopy fires and replacement of forest by chaparral and hardwood forests (McKelvey and Johnston 1992).

In contrast, historical descriptions of SSPM vegetation reveal that the composition, structure and distribution of conifer forests was remarkably similar to that seen presently, despite widespread periodic fire the past two centuries (Minnich and Franco Vizcaíno, in review). In 1792, Longinos Martinez described pine forest along a cattle trail between Valladares and La Grulla in words that would equally well describe the same vegetation there today. In 1888, SPM forests were examined in detail in an extraordinary 76-day survey by Col. D.K. Allen. Allen

recorded nearly the same species composition and tree diameter size frequency distribution recorded in our transects.

In recent years, increasing pressure has been placed on cattlemen to refrain from setting fires. Moreover, since foresters have presumed that most fires are initiated by man, ranchers might be punished just because fires occur on their land. Because lightning is a more important source of fire than has been realized, false accusations will become inevitable. Cloud-to-ground lightning is a significant source of fire in SSPM. The U.S. Bureau of Land Management lightning detection system, which covers Baja California north of lat. 31°, recorded an average of 1.5 strikes per 1,000 ha per year. Moreover, only a low percentage of cloud-to-ground lightning strikes leading to fires is sufficient to establish the complex patch structure seen now in SSPM (Minnich et al 1993).

Large and catastrophic fires may result in SSPM if fire suppression is instituted; this will offer little advantage to cattlemen. Small burns improve local forage and access, whereas large fires cause cattle to become dispersed or lost and the area is left without pasture (Meling Pompa 1991 a,b). Conversely, an unmanaged fire regime on the SSPM plateau poses a small threat to structures because the sierra is not permanently inhabited. Only the observatory should be protected, but its protection should not based upon fire control throughout SSPM, nor would such an effort be desirable for reasons discussed above.

In a future SSPM biosphere reserve, scientists, land managers and ranchers should be exposed to alternative views of wildland fire with respect to the grazing economy and its influence on natural ecosystems. Hence, it is imperative that managers consult with ranchers for knowledge of winds, annual climate shifts, and past fire histories (Gomez Pompa and Kaus 1992). Foresters should also critically examine the "well-managed" status of their own forests, as well as the mistakes made in a similar ecosystem because of fire suppression in California. Indeed, a passive response to wildfire and controlled burning of mature vegetation may be a good option for management in a region where natural fire has shaped landscapes.

Logging

Recently, a multi-national forest products company has begun operations in the industrial park north of Ensenada. Most of the lumber products at this facility originate in the U.S Pacific Northwest for processing at the El Sauzal plant. Heavy trucks have been observed transporting large Jeffrey pine logs down the observatory road, presumably enroute to El Sauzal. Logging is legal in the ejido lands surrounding the National Park, but is not legal within the park boundaries.

Selective logging may be a useful supplemental tool in the sustainable management of SSPM forests on ejido lands, and perhaps in the park, but on a very limited basis. Studies in California have shown that clear-cut logging of areas > 2 ha is incompatible with the health of mediterranean mixed conifer forests because the development of mature forests is dependent upon the selective mortality of saplings and polesize trees rather than commercially valuable old growth trees. Removal of overstory trees invariably leads to the establishment of chaparral and dense, young-

growth forests with high fire hazard. This enhances the potential for catastrophic canopy fires and degradation of the ecosystem. Based upon the experience from California, clear-cutting even stands >2 ha, using current lumbering technology, would cause extensive destruction and destabilization of SSPM forests. Cutting of dead trees could threaten the endemic bat *Myotis milleri*, which apparently requires them for sleeping places (Mellink Bijtel 1991). Unfortunately, the Federal Mexican Government is promoting legislation that would liberalize current logging restrictions throughout the country.

Wildlife management

Although several large mammals and the California condor have become locally extinct during the past century, the isolation and pristine landscape of SSPM has preserved the rich diversity of wildlife of the region. A potential conflict in a biosphere reserve will be the hunting of megafauna which tend to have low reproductive rates. Hunting is prohibited within the national park, but is permitted outside the park on the eastern escarpment and southern third of the range. The development of a game management system will require compromise between conflicting needs of land managers and users.

The primary game animal in SSPM in recent decades has been the bighorn sheep (*Ovis canadensis cremnobates*) living on the eastern escarpment. Controlled hunting of this animal, under authority of the Mexican government (SEDUE), has been permitted as recently as the late 1980s (Aguilar Rodríguez 1991, Mellink Bijtel 1993). Sheep hunting apparently led to minimal conflict with cattle ranchers because of the virtual isolation of the eastern escarpment from cattle operations on the plateau. Sheep are now under total protection as hunting operations ceased in 1990 by decree of President Carlos Salinas as the result of conflicts and conflicts of interest among wildlife protection groups and hunting associations (Mellink Bijtel 1993). Deer are common throughout the forest plateau, but is not extensively hunted because most populations exist within the national park. However, the extent of poaching within the national park is unknown.

Protection of the Kiliwa Indians

As a result of their historic isolation, the Kiliwa Indians (as well as the neighboring Paipai in the southern Sierra Juárez) are the last Indian populations that speak native languages and practice a hunting and gathering economy along the Pacific coast from Canada to the tip of Baja California. The cultural and social heritage of the region has been documented by research program of the National Institute of Social Research (IIS) of the Autonomous University of Baja California and the National Institute of Anthropology and History (INAH) that complements the database of the MAB project (Bendimez Patterson 1991). Her research includes locating and recording archaeological sites, recording rock art by photography, and recording the oral information of indigenous peoples with a view toward searching for strategies to conform with the ecological resource base of the region.

There appears to be little resource conflict between ejidos and Kiliwa settlements

concentrated along Arroyo León where pasture is limited. However, over the past 10 years there has been a rapid expansion of a ranch with headquarters located at lat. 31° 10'N, 155° 33'W, which includes construction of numerous roads, tanks, and other infrastructure within Kiliwa territory as recognized by Meigs (1939).

EVALUATION/RECOMMENDATION: DEVELOPMENT, STRUCTURE, AND MANAGEMENT OF A BIOSPHERE RESERVE.

Until recent decades SSPM has remained in isolation. The impact of livestock grazing on biotic resources has been small, and it therefore appears to be sustainable in maintaining the region's diverse biotic resource. Dominant species in forests, meadows, and chaparral appear well-adapted to periodic fire, browse, and geomorphic disturbances.

SSPM is isolated not only because of the rugged and inaccessible nature of the region, but also to the broader trends of economic development in northern Baja California. During the 20th century, urban and agricultural growth has concentrated in the rich Mexicali Valley and the border cities. However, the opening of the transpeninsular highway contributed to rapid growth of agriculture and establishment of ejidos and villages along the San Quintín coastal plain and San Telmo Valley. The observatory road, which opened the region to the outside world in the early 1970s, presents both threats and opportunities. Threats from fire suppression, economic development, and increasing recreation pressure may result in irreversible changes that will make SPM forests indistinguishable from forests in the United States. These threats may become opportunities in a biosphere reserve if an institutional infrastructure were to be established between the rural population, land managers, and scientists. Such infrastructure could help the development of a sustainable system for the protection of extraordinary ecosystems unique to México.

Indeed, institutional infrastructure is already in place for a biosphere reserve. Portions of SSPM exist as a national park under SARH. Scientific infrastructure exists within the National Park. Many research institutions in northern Baja California and the adjoining U.S. have supported research on terrestrial biology and ecology, conservation, anthropology, archaeology, and history of SSPM (Franco Vizcaíno and Sosa Ramírez 1991; Table 8).

An International Conference on the Potential of the Peninsular Range of the Californias as a Biosphere reserve was held in Ensenada on March 18-19, 1991. Support for such a reserve was expressed by all sectors that attended the conference. However, the concept of a biosphere cluster involving five reserves along the Peninsular ranges on both side of the International Border may have been too ambitious to gain confidence among participants. The primary problem is that the concept could not bridge across the contrasting economies of México and the United States (Ojeda et al 1991). They felt that efforts toward a binational biosphere reserve should proceed cautiously because the coordination of efforts in both countries will be strained by differences in their economic structures and attitudes toward conservation. Moreover, the lands of indigenous cultures often cross the international boundary. In addition, park systems created by legislation in

western industrial countries are supported by residents, but demographic pressures in developing countries, such as México, result in the occupation of protected areas by landless peasants whose only chance for survival lies in subsistence agriculture (Halffter, 1981; Gomez Pompa and Kaus 1992).

The fate of a reserve rests upon the support of the rural population. To date there has been too little collaboration with interested individuals in the rural sector. This view was crystallized by Meling Pompa, who stated during the conference, "We have tried to tell you our concept of the San Pedro Mártir, but we don't understand the biosphere reserve. But you guys are not in accord [i.e, the participants of the conference]. This is not a bad thing, but we live there. We intervene directly and ask direction from you fellows how things are to be done."

The implementation of a biosphere reserve will require the establishment of a legal organization which assures the integration of the rural population with others working in the reserve. We propose the establishment of a civil organization to run the biosphere reserve and represents the interests of all parties. The civil organization should have a governing board that includes academics, land managers, and the rural population. That board would be in charge in administering the biosphere reserve and would have the authority to charge fees for hunting, camping, and ecotourism. It should also disperse funds to support scientific research and maintenance of infrastructure. The board should also include representatives of the ejidos, as well as the guest ranches, which already have, for example, infrastructure for ecotourism.

There was consensus at the conferences that the SSPM alone could stand as a biosphere reserve. Afterwards, if sister reserves are created in the U.S., a binational understanding relating them in a stronger way might be feasible. A SSPM biosphere reserve was also strongly endorsed by the Commission of the Californias (Barry 1991).

Biosphere Reserve Structure and Management

The delimitation of core, buffer, and transition zones of a SSPM biosphere reserve will depend upon prospective resource goals agreed upon between the rural population, managers, and scientists. It is anticipated that a biosphere reserve in SSPM will be defined by several of the resource values identified above. The reserve borders should not modify the National Park boundaries, nor boundaries of the "Kiliwa reservation." Only the landuse activities within the National Park and the reserve need to be adjusted.

A landuse plan and attendant boundaries for a biosphere reserve must be mediated by those directly involved in the region, but the following illustrates how a biosphere reserve that conserves resources and makes use of the grazing resource and extant infrastructure might be organized. The proposed reserve boundaries are shown on Fig. 5. This scenario has full consensus of our research team.

Biosphere "Cores"

The primary biosphere "core" should probably be located along the eastern rim of Vallecitos and include the observatory which requires strict control of land use and access. The core should be large enough to accommodate its defining activities. For example, the observatory infrastructure is confined to the eastern edge of Vallecitos, but recreation needs may require development of campground, research and education zones in other portions of Vallecitos. The core may include a research field station and perhaps a headquarters for government agencies resonsible for the environment. For research purposes, the mixed conifer forest north of Vallecitos to Cerro Venado Blanco and Rancho Nuevo could also be included in the "core."

In our plan we defined the primary core as those lands in SSPM that are above 2,000 m altitude and north of lat. 31° (Fig. 5).

There are several reasons for the core in this area: 1) A core designation protects the interests of the National Observatory. 2) The area includes some of the most diverse mixed conifer forest of SPM. 3) much formal research in SSPM to date has taken place in the Vallecitos region. 4) The livestock industry would not be severely impacted because the grazing resource in eastern Vallecitos meadows is minor compared to more verdant meadows farther south. Forests north of Vallecitos have only small meadows, but the richest mixed conifer forests of SSPM. 5) Vallecitos has good access for maintenance of infrastructure. 6) Access fascilitates the recreation and the education function, as well as special research objectives (for example: permitting transport of heavy fencing for exclosure studies).

A second core could be established in Kiliwa lands; this could include traditional use lands, and an anthropology research laboratory located at the edge of the reserve possibly near Valle Trinidad. The Kiliwa now survive in small numbers and are perilously close to vanishing. Every effort should be made to place the entire Kiliwa "reserve" in immediate protection as a "core," to prevent external development from undermining Kiliwa culture. As discussed by Bendimez Patterson (1991), a research program needs to be implemented that records Kiliwa culture, language, and their use of the land. There should also also be an archaeological survey for sites in SPM. Part of this survey should include the San Pedro Mártir mission site.

Buffer and Transition Zones

The designation of buffer and transition lands could make use of existing land ownership. Buffer zones should include lands used seasonally for cattle grazing, and under protection of the National Park, and areas set up for controlled hunting. These include the eastern and western escarpments, and grazed areas south of the Vallecitos plateau. Ejido lands might be placed under transition zones to accommodate their natural economic development.

In our plan we define the "buffer zone" as those lands above 1,000 m altitude on the eastern escarpment, and above 1,500 m on the western escarpment. To include Kiliwa lands in the northwest part of the reserve, the western border is extended from the 1,500 m contour 0.7 km

south of the settlement of El Huico, to El Huico, then follows a road from El Huico to La Cieneguita, to Cañada La Parba and La Parra. From La Parra the border follows the west boundary of the Kiliwa Reserve northeastward to where it meets the 1,000 m contour again at 31° 20' N, 115° 40' W.

Such a plan would protect the natural resources of the mountain, permit the continuation of seasonal cattle grazing, and allow economic development in lands immediately surrounding the sierra. Restricted land use in a buffer zone will be necessary for the protection of SSPM resources highlighted below. For each resource discussed below, research topics are suggested that will require coordination between scientists, land managers, and the rural population.

Mission San Pedro Mártir de Verona

The mission site consists of adobe ruins, an extensive scatter of artifacts, some irrigation canals, and former cultivated fields. Unlike many other mission sites, the San Pedro Mártir mission has not been pillaged by looters or destroyed by urbanization. It consequently has the potential for economic benefit to a biosphere reserve as an ecotourism site as part of an accompanied wilderness tour. The mission site's altitude (1,600 m) places it within the buffer zone.

Potential research to accomplish biosphere land use and management: Archaeological surveys of the mission site and other sites related to Dominican mission efforts, such as Casilepe, can be carried out in conjunction with surveys of prehistoric archaeology.

Game Species

Game species, such as the mountain sheep (*Ovis canadensis cremnbates*) and quail could be a valuable potential resource for the proposed biosphere reserve. For this reason, the present policy of complete prohibition of hunting (Mellink Bijtel 1993) should be reconsidered. Hunting may help to regulate populatons or increase numbers in depleted species. For example, the protection of the puma from bounty hunters in California, which began in 1972, resulted in a rapid increase in its population. Sport hunting may be a financial resource to sustain the scientific objectives and management of the biosphere reserve.

The eastern escarpment of SSPM supports the largest population of Peninsular Range bighorn sheep. At present hunting of mountain sheep under moratorium (Mellink Bijtel 1993), until a helicopter survey by the Bighorn Institute and funded by the Méxican government is completed. The policies undertaken should reflect the census data compiled by the Bighorn Institute.

If permit hunting is implimented in the future, the moneys obtained should be allocated for wildlife management in Baja California. The lucrative moneys generated by sheep tags will also require strict permitting procedures under federal control. Hunters should be escorted by expert land managers. Hunting must be paralleled by the development of scientific databases on sheep numbers, gender distribution, foraging characteristics and other parameters. Knowledge of short-

term population dynamics will be necessary to estimate the number of hunting permits. Sheep should be placed in a "buffer zone" status to ensure tight regulation, even though most habitat is nearly inaccessible. This is accomplished by defining the eastern boundary of the biosphere reserve with the 1000 m contour.

Hunting may be a mechanism which integrates ejidos east of SSPM into the activities of a biosphere reserve. Another source of income for eastside ranches may be a permit or guide system for mountain/rock climbing in the precipices of eastern escarpment, such as Picacho del Diablo.

Potential research to accomplish biosphere land use and management: Population dynamics, ecology, migratory habits and diet of mountain sheep. Evaluation of competitive interactions of mountain sheep with feral burros, deer, and other megafauna.

Rainbow Trout.

Buffer zone land use restrictions will be necessary to protect the few populations of the rainbow trout (*Oncorhynchus mykiss nelsonii*) from overfishing. Many native fish species in southern California, also living in marginal streams, were quickly fished out to extinction before protection measures could be established. Under the proposed biosphere boundaries, most populations in Arroyos San Antonio and San Rafael are protected. Research should be done to evaluate how to manage this population sustainably with respect to stream sedimentation and eutrofication due to grazing.

Potential research to accomplish biosphere land use and management: Continuation of studies building on the work of Ruiz-Campos and Cota-Serrano. Habitat, especially population dynamics with fluctuating stream floods and drought, transplanting fish to other streams. Efforts should be made to prevent the introduction of other fish species that could compete with this endemic.

Protection of endemic or rare plant species.

The SSPM contains several species that are rare or endemic to the sierra. *Cupressus montana* and several forbs receive natural protection because their distributions are restricted to the precipitous eastern escarpment. Conversely, several others are confined to meadow habitats subject to grazing. In our exclosure studies we found that some endemics, such as *Ophiocephalus angustifolius*, thrive with grazing disturbance. However, our knowledge of most rare or endemic species is limited. Hence, the implementation of a sustainable management system for these species will require formal research on the ecology of these endemics and their adaptation to land use disturbances.

Potential research to accomplish biosphere land use and management: Studies on the genetics, ecology, habitat and population characteristics of endemic species. Foraging of

endemics or other browse species occurring on the eastern escarpment by bighorn sheep.

Livestock grazing.

Economic incentives encourage overgrazing. Thus, a biosphere reserve may be an excellent mechanism to maintain sustainable grazing, supported by scientific research. Since the primary meadows occur within the National park, cooperative arrangements have already been made between cattlemen and SARH. Under the proposed biosphere reserve, both meadows within the National Park and in southern SSPM (Santa Rosa, Santo Tomás, Santa Eulalia) would come under a buffer zone status. This is done to sustain the present system of seasonal cattle grazing.

Cooperative arrangements can be refined for the purposes of a biosphere reserve. This will also require that land managers and scientists learn the views of cattlemen concerning the pastoral resource. Cattlemen can also play the role of informed caretakers of the sierra, by expanding their activities within the biosphere reserve framework. More research will be required to establish the relationship between the intensity of cattle grazing and degradation of the meadows. We believe that much of the SSPM plateau (including the meadows and routes of the seasonal cattle drives) could be placed in a buffer zone, because meadows are so resilient and the chaparral and forests are not utilized by the animals. Meadows outside the park, such as Santa Rosa and those of Santa Eulalia should also be placed in a buffer zone to prevent overgrazing in these areas.

Potential research to accomplish biosphere land use and management: Research on cattle impacts will require long-term monitoring on the impact of grazing on meadow biomass and species composition through exclosure studies. In addition to our baseline study at Vallecitos, new exclosures should be established at the primary meadows in central SPM. Studies could utilize existing exclosures (such as COTECOCA) and preexisting fencing. Other issues that should be addressed are the impacts of livestock on soil, ground water, and stream nitrification. Some megafauna, such as deer, may also lose habitat because of cattle grazing.

Mixed conifer forest, chaparral, and fire suppression.

Californian mixed conifer forests of SSPM grow above 1,800 m and nearly all stands would come under either core or buffer zones. A SPM biosphere reserve may serve as a showcase for research in fire ecology for similar ecosystems throughout the southwestern United States and northwestern México. Furthermore, a natural fire regime will result in forests and chaparral that require much less funding to manage, and in the end are less threatening to the livestock industry, life and property.

The research team strongly recommends that biosphere reserve management not adopt the outmoded fire suppression policies of industrialized countries. Fire control should be strictly limited to the immediate vicinity of the "core" zone infrastructure. Fires should be allowed to run their course in the remainder of SSPM. Evidence is strong that periodic fires over the past

centuries have had little impact on these fire-resilient ecosystems.

SSPM mixed conifer forests also require protection because they are unique to México in species composition. Moreover, the isolation of SSPM forests from the nearest stands in California (300 km north) may have contributed to genetic differentiation of several trees and shrubs. *Abies concolor* in SSPM, for example, have abnormally thick needles (Vasek, 1985). Tom Ledig (pers. comm.) states there is more genetic variation in *Pinus coulteri* among the rare populations of northern Baja California than among the extensive forests in California. The montane chaparral species *Arctostaphylos patula* and *Ceanothus cordulatus* in SPM grow to as tall as 2-3 m, while in California forests they are normally prostrate at <1.5 m stature. *Quercus chrysolepis* has small leaves and is shrubby compared to California populations.

Potential research to accomplish biosphere land use and management: The SSPM as a natural fire laboratory will permit research in fire ecology that is not possible in industrialized countries where fire control has already modified fire regimes and vegetation for nearly a century. Research in fire ecology in industrialized countries has been retrospective through examination of historical literature and methods such as tree-ring fire chronologies and stand age class reconstructions. Natural fire regimes can be documented on a "real-time" basis and can include studies on fire behavior, vegetation damage, burn patch dynamics, long-term monitoring of postfire succession, and other fire-related phenomena. The isolation of SSPM forests may yield valuable information on forest genetics.

Reintroduction of the California Condor.

An excellent and timely issue for the establishment of a biosphere reserve would be cooperative conservation efforts among the governments of Alta and Baja California toward the restoration of the magnificent California condor (*Gymnogyps californianus*) to SSPM. The success of captive breeding programs at San Diego and Los Angeles zoos now presents an opportunity to release birds into favorable habitats, such as SSPM. Indeed, the study team believes that the Condor has a greater chance for successful naturalization in SSPM than the Sespi Reserve in California, where the last birds were captured.

The eastern escarpment of SSPM contains abundant cliff faces and ledges favorable to their roosting and nesting. Updrafts associated with the high relief are also favorable for soaring. Chaparral and other plant ecosystems have diverse patch structure, which are favorable for a plentiful food resource base for the bird. Burned patches provide sites for easy take-offs and landings. In contrast, the Sespi Reserve contains extensive stands of dense chaparral which limits the bird's access to carrion. Condor mortality there has been caused by lead poisoning, consumption of antifreeze, and collision with man-made structures such as powerlines.

The reintroduction of the California condor to SSPM may serve both as a focal rallying point toward a biosphere reserve by local populations and land managers, and as a management centerpiece for the establishment of a biosphere reserve, because such an effort would bring

international attention and require the integration of sustainable management of other natural resources. For example, limited fire control to maintain fine-grained chaparral patch structure and open forest structure may be necessary to optimize habitat for the bird. Livestock grazing adds a carrion resource. The reintroduction of condors will also require strict controls on escorted trophy hunting of Bighorn sheep. This effort will require coordination with neighboring ranches to minimize use of toxic materials. The reintroduction of condors, of course, will require coordinated efforts with research U.S. institutions committed to the breeding and release of California condors.

Potential research to accomplish biosphere land use and management: Studies on home range and distribution of activity. Naturalization of released birds. Condor population ecology and diet preference vis-a-vie, mountain sheep, deer, small game, livestock, as well as marine mammals, birds and fish. Adaptation of condors to natural disturbance. Human/Condor interactions off the sierra.

CONCLUSION

As a biosphere reserve, Sierra de San Pedro Mártir can serve as an extraordinary resource for a number of purposes beneficial to México and the international community.

For Mexico, a biosphere reserve will help conserve a region of striking diversity and geographic isolation that includes many rare and endemic species.

The Sierra San Pedro Mártir can also serve as an extraordinary "showcase" of ecosystems functioning under natural disturbance at the landscape scale and under a traditional management system for comparison with similar temperate ecosystems under other management elsewhere. The sierra also hosts a grazing economy preserved from the 19th century and a small Indian population. The habitat is also suitable for an experiment of international importance: the reintroduction of the California Condor.

There is already historical precedent for the protection of SSPM through the establishment of the Sierra San Pedro Mártir National Forest Reserve and the Sierra San Pedro Mártir National Park, and significant infrastructure exists within the region. Scientific expertise exists in terrestrial ecology, anthropology and related subjects, a research infrastructure of the National Observatory. Scientific expertise can be utilized for the development of an education function in the reserve.

A tour approach employed for activities such as visits to the San Pedro Mártir archaeological site, rock climbing, condor tours, and other activities, will foster an increased sense of stewardship by the local population over the historic, archaeological, and biological sites within a biosphere reserve.

Our multidisciplinary research group has developed a baseline database that resulted from studies in climatology, hydrology, ecology, fire history, grazing impacts, and archaeology from which a larger body of research can arise to mediate existing landuse with biological conservation.

A biosphere management plan could employ most aspects of the current economy and land use. Thus, the transition to a biosphere reserve can be readily undertaken without undermining the activities of the rural population. To accomplish the goal of developing a biosphere reserve will require further dialogue between participants, and possibly another conference devoted solely to the Sierra San Pedro Mártir.

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Table 1: Average summer, winter, and annual precipitation in the Sierra San Pedro Martir.

Station/alt (m)	Year	Santa Cruz	West slope 1500	West slope 2000	West plateau 2500	East plateau 2400	North plateau[1] 2350	Central plateau[1] 2200
				Winter (October-May)				
Oct 1- Apr 7	90	10.6	19.2	27.4	28.8	24.5	-	-
Sep 25 - May 17	91	31.4	48.0	56.1	58.4	44.6	52.6	37.4
Oct 10 - May 22	92	39.6	50.7	60.3	65.6	49.7	53.9	44.6
Mean (1990-92)		27.2	39.3	47.9	51.0	39.3	53.2	41.0
Adjusted mean[2]		23.4[3]	33.8	41.2	43.9	33.8	35.1	27.0
				Summer (May -October)				
Apr 7- Sep 25	90	1.3	10.8	25.9	25.2	20.7	14.1	10.9
May 17 - Oct 10	91	0.3	8.3	7.0	8.3	15.0	8.3	10.1
May 22 - Sep 17	92	3.9	12.7	27.9	15.2	14.2	21.4	16.9
Apr 15 - Sep 13	93	1.6	-	-	-	8.0	7.0	11.7
Mean (1990-93)		1.1[3]	10.6	20.3	17.3	14.5	12.7	12.4
				Annual (OCT-SEP)				
1989-90		11.9	30.0	53.3	54.0	45.2	-	-
1990-91		31.7	56.3	63.1	66.7	59.6	60.9	47.5
1991-92		42.5	63.4	88.2	80.8	63.9	75.3	61.5
MEAN[4]		24.5	44.4	61.5	61.2	48.3	47.8	39.4

1. Remote stations, measurements twice a year in October and May.
2. Adjusted means (1990-92) weighted against annual precipitation departures from the 1959-93 at Rancho Santa Cruz.
3. Mean 1959-93 precipitation at Rancho Santa Cruz.
4. Mean annual precipitation = adjusted winter precipitation + nonadjusted summer precipitation.

Table 2. Snowpack measurements in the Sierra San Pedro Mártir.

Site	Date	Snow Depth (cm)	+/-	Water Content (cm)	+/-	Density %	+/-	No. Observations
Observatory	9 Mar 91	30.6	4.2	12.6	1.2	40.2	3.2	8
	3 Apr 91	70.1	11.1	27.3	7.2	38.8	7.6	12
	7 Jan 92	33.0	6.3	8.3	3.7	23.4	7.1	5
	12 Mar 92	91.4	15.8ab	33.8d	-	-	-	4
Vallecitos	10 Mar 91	35.3	8.4	13.1	3.1	37.2	0.0	8
	7 Jan 92	20.0	3.2	7.4	1.2	37.2	0.0	8
	12 Mar 92	31.8	4.9	11.7	1.8	37.3	0.1	8
	22 Dec 92	23.5	1.4	8.7	5.3	37.2	0.0	5
La Corona	10 Mar 91	49.4	3.4ab	34.9	3.0	70.8	6.6	8
	7 Jan 92	27.3	6.5	8.1	2.7	30.0	7.3	8
	12 Mar 92	91.8	12.2acf	65.2ef	-	-	-	12
	22 Dec 92	38.5	1.6	13.2	1.4	34.4	4.8	5
La Puerta	22 Dec 92	17.2	0.5	6.4d	-	-	-	-

a. lower snowpack icy
b. great difficulty boring down to soil
c. unable to bore down to soil
d. estimated by using density of 37%
e. estimated by using density of 71%
f. probably an underestimate.

Table 3. Common species of selected plant communities in northern Baja California north of the 30th parallel (Spanish plant names from Moran 1977; Roberts 1989; Tiscareno and Robinson 1969; Martinez 1947).

Species	Common name
	Chaparral
Adenostoma fasciculatum	Chamise, Chamiso, Vara Prieta
A. sparsifolium	Redshank, Chamiso de Vara Colorada
Arctostaphylos glauca	Bigberry Manzanita, Manzanita
A. peninsularis	Peninsula Manzanita, Manzanita
Ceanothus cuneatus	Ceanothus, Lilac, Bracillo
C. greggii	Desert Ceanothus, Lilac, Bracillo
C. leucodermis	Chaparral Whitethorn, Ceanothus, Bracillo
Nolina parryi	Nolina, Palmita
Q. cornellius-mulleri	Desert Scrub Oak, Encinillo, Encinito Chaparro
Quercus dumosa	Scrub Oak, Encinillo, Encinito Chaparro
Rhus ovata	Sugarbush Sumac, Lentisco
Yucca schidigera	Mojave Yucca, Dátil, Dátillo
Juniperus californica	California Juniper, Huata, Cedro, Ciprés
P. quadrifolia	Parry Pinyon, Four-needle Pinyon, Piñon
P. coulteri	Coulter Pine, Pino
Platanus racemosa	Western Sycamore, Aliso
Populus fremontii	Fremont Cottonwood, Poplar, Alamo
Quercus agrifolia	Coast Live Oak, Encino, Enzino
Q. chrysolepis	Canyon Live Oak, Encino
	Pinyon Forest
Juniperus californica	California Juniper, Huata, Cedro, Ciprés
Pinus monophylla	Singleleaf Pinyon, Piñon
P. quadrifolia	Parry Pinyon, Four-needle Pinyon, Piñon
A. peninsularis	Peninsula Manzanita, Manzanita
Cercocarpus betuloides	Birch-leaf Mountain Mahogany, Ramón
Garrya grisea	Silktassle Bush
Nolina parryi	Nolina, Palmita
Prunus ilicifolia	Holly-Leaf Cherry, Islay
Q. cornellius-mulleri	Desert Scrub Oak, Encinillo, Encinito Chaparro
R. kearneyi	Sumac, Lentisco
Rhus ovata	Sugarbush Sumac, Lentisco
Yucca schidigera	Mojave Yucca, Dátil, Dátillo
	Mixed conifer forest
Abies concolor	White Fir, Abeto, Pino Blanco

Calocedrus decurrens	Incense Cedar, Cedro Incienso, Ciprés
Cupressus montana	Mountain Cypress, Ciprés, Cedro de la Sierra
Populus tremuloides	Quaking Aspen, Alamillo, Alameda Tremblón
Pinus contorta	Lodgepole Pine, Pino
P. jeffreyi	Jeffrey Pine, Pino Ponderosa
P. lambertiana	Sugar Pine, Pino
Quercus chrysolepis	Canyon Live Oak, Encino
Q. peninsularis	Pacific Emory Oak, Encinillo
Arctostaphylos patula	Green-Leaf Manzanita, Manzanita
A. pringlei	Pinkbract Manzanita, Manzanita
A. pungens	Mexican Manzanita, Manzanita
Artemisia tridentata	Great Basin Sage, Chamiso Blanco
Ceanothus cordulatus	Snowbush Ceanothus, Lilac, Bracillo
Garrya grisea	Silktassle Bush
Rhamnus californica	Coffeeberry, Yerba de Oso
Salvia pachyphylla	Rose Sage, Salvia Rosa
Symphoricarpos parishii	Snowberry

Creosote bush scrub/microphyllous woodland/ Central Desert scrub

Acacia greggii	Catclaw, Cimmarón, Zimmarón
Agave desertii	Desert Agave, Agave, Mescal,
Ambrosia dumosa	Bursage
Cercidium floridum	Palo Verde, Ypúa, Dipúa, Medeja, Medesa
Echinocereus engelmannii	Hedgehog Cactus
Encelia farinosa	Brittlebush, Incienso
Fouqueria columnaris	Boojum Tree, Cirio
F. splendens	Ocotillo, Palo Adán
Larrea tridentata	Creosote Bush, Gobernadora
Lemairocereus thurberi	Organ Pipe Cactus, Sweet Pitahaya, Pitahaya Dulce
Opuntia acanthocarpa	Buckhorn Cholla
O. basilaris	Beaver-tail Cactus, Prickly Pear, Nopal, Tuna
O. echinocarpa	Silver Cholla
Olneya tesota	Desert Ironwood, Palo Fierro, Uña de Gato, Ypúa, Dipúa
Pachycereus pringlei	Cardón
Prosopis juliflora	Mesquite, Mezquite
Prosopis glandulosa	Honey Mesquite, Mezquite

Palm Oases

Brahea armata	Blue Fan Palm, Palma Ceniza, Palma

Table 4: Characteristic Mammals of the Sierra San Pedro Mártir (after Nelson, 1921 and Bond, 1977; Mellink-Bijtel 1991).

Species	Common name
Chaparral	
Onychomys torridus	Southern Grasshopper Mouse
Peromyscus maniculatus	Deer Mouse
Peromyscus californicus	California Mouse
Peromyscus eremicus	Cactus Mouse
Reithrodontomys megalotis	Western Harvest Mouse
Neotoma lepida	Woodrat
Neotoma fuscipes	Woodrat
Thomomys bottae	Pocket Gopher
Dipodomys merriami	Merriam's Kangaroo Rat
Perognathus longimembris	Pocket Mouse
Perognathus fallax	San Diego Pocket Mouse
Perognathus californica	Pocket Mouse
Lepus californicus	Black-tailed Jackrabbit
Sylvilagus auduboni	Audubon Cottontail
Sylvilagus bachmani	Bachman's Audibon Cottontail
Ammospermophilus leucurus	White-tailed Antelope, Ground Squirrel
Thomomys umbrinus#	Pocket Gopher
Procyon lotor	Raccoon
Taxidea taxus	Badger
Mephitis mephitis	Striped Skunk
Sorex californicus	California Shrew
Sorex ornatus	Ornate Shrew
Mixed conifer forest	
*Tamiasciurus mearnsi**	Douglas Squirrel, SPM Chickaree
Eutamias obscurus#	Merriam Chipmunk
Spoermophylus beecheyi	Beechy Ground Squirrel
Chaetodipus californicus#	California Pocket Mouse
Peromyscus truei#	Pinyon Mouse
Peromyscus maniculatus	Deer Mouse
Peromyscus boylii	Brush Mouse
Microtus californicus#	California Vole
Neotoma lepida	Woodrat
Neotoma fuscipes	Dusky-footed Woodrat
Spilogale putorius	Skunk
Scapanus latimanus#	Broad-footed Mole
Myotis subulatus	Myotis Bat
Myotis yumanensis	Yuma Myotis

*Myotis milleri**	Myotis Bat
Myotis orinomus	Myotis Bat
Myotis evotis	Long-eared Bat
Eptesicus fuscus	Big Brown Bat
Pipistrellus hesperus	Western Pipistrelle
Tadarida brasiliensis	*Brazilian Free-tailed Bat*
Tadarida femorasacca	*Free-tailed Bat*
Megafauna	
Ovis canadensis cremnbates	Mountain Bighorn Sheep
Felis concolor	Mountain Lion, Cougar, Puma
Lynx rufus	Bobcat
Odocoileus hemionus	Mule Deer
Canis latrans	Coyote
Urocyon cinereoargenteus	Gray Fox
Bassariscus astulus	**Ringtail**

* Species endemic to SSPM
\# Subspecies endemic to SSPM

Table 5: Characteristic Birds of the Sierra San Pedro Mártir (after Nelson, 1921; Kratter, 1991, 1992; American Ornithologists' Union, 1983; Rodriguez-Meraz 1993).

SPECIES	COMMON NAME
Chaparral	
Phalaenoptilus nuttallii	Common Poor-will
Archilochus alexandri	Black-chinned Hummingbird
Tyrannus verticalis	Western Kingbird
Eremophila alpestris	Horned Lark
Sturnella neglecta	Western Meadowlark
Aphelocoma coerulescens#	Scrub Jay
Euphagus cyanocephalus	Brewer's Blackbird
Agelaius phoeniceus	Red-winged Blackbird
Carpodacus mexicanus	House Finch
Carduelis lawrencei	Lawrence's Goldfinch
Carduelis psaltria	Lesser Goldfinch
Passerculus sandwichensis	Savannah Sparrow
Amphispiza belli	Sage Sparrow
Aimophila ruficeps#	Rofous-crowned Sparrow
Melospiza melodia	Song Sparrow
Thryomanes bewickii#	Bewick's Wren
Pipilo fuscus#	Brown Towhee
Passerina amoena	Lazuli Bunting
Lanius ludovicianus#	Loggerhead Shrike
Vireo bellii	Bell's Vireo
Vireo vicinior	Gray Vireo
Toxostoma redivivum	California Thrasher
Toxostoma dorsale#	Crissal Thrasher
Parus inornatus#	Plain Titmouse
Psaltriparus minimus#	Bushtit
Chamaea fasiata#	Wrentit
Polioptila californica#	California Gnatcatcher
Pipilo erythrophthalmus	Rufous-sided Towhee
Callipepla californica#	California Quail
Charadrius vociferus	Killdeer
Asio otus	Long-Eared Owl
Otus kennicotti	Western Screech Owl
Ardea herodias	Great Blue Heron
Chordeiles accutippenis	Lesser Nighthawk
Calyte anna	Anna's Hummingbird
Sphyrapicus ruber	Red Breasted Sapsucker
Regulus calendula	Ruby-Crowned Kinglet

Sialia mexicana#	Western Bluebird
Catharus guttatus	Hermit Thrush
Myadestes townsendi	Townsend's Solitare
Toxostoma cinereum #	Gray Thrasher
Bombycilla cedorum	Cedar Waxwing
Pheuctitus melanocephalus	Black-Headed Grosbeak
Sayornis nigricans#	Boack Phoebe
Sayornis saya#	Say's Phoebe
Myarchus cinerascens	Ash-Throated Flycatcher
Pyrocephalus rubinus	Vermillion Flycatcher
Passerela iliaca	Fox Sparrow
Wilsonia pusilla	Wilson's Warbler
Icterus cucllatus	Hooded Oriole
Loxia curvirostra	Red Crossbill

Mixed conifer forest

Strix occidentalis	California Spotted Owl
Gymnorhinus cyanocephalus	Pinyon Jay
Melanerpes formicivorus#	Acorn Woodpecker
Picoides nuttallii	Nuttall's Woodpecker
Picoides villosus	Hairy Woodpecker
Oreortyx pictus#	Mountain Quail
Columba fasciata	Band-tailed Pigeon
Colaptes cafer auratus#	Northern Flicker
Empidonax difficilis	Western Flycatcher
Contopus borealis	Olive-sided Flycatcher
Junco hyemalis#	Dark-eyed Junco
Piranga ludoviciana	Western Tanager
Progne subis	Purple Martin
Tachycineta thalassina	Violet Green Swallow
Vireo solitarius	Solitary Vireo
Dendroica coronata	Yellow-rumped Warbler
Troglodytes aedon	House Wren
Sitta carolinensis#	White-breasted Nuthatch
Sitta pygmaea#	Pigmy Nuthatch
Parus gambeli#	Mountain Chickadee
Carduelis pinus	Pine Siskin
Carpodacus cassini	Cassin's Finch
Stellula calliope	Calliope Hummingbird
Accipiter striatus	Sharp-Shinned Hawk
Sphyrapicus thyroideus	Williamson's Sapsucker
Nucifraga columiana	Clark's Nutcracker

Subspecies endemic to SSPM

Table 6: Rare and/or Endemic* Plant Species of the Sierra San Pedro Mártir
(After Moran 1977; Wiggins, 1980; R.F. Thorne, pers. comm.).

Family	Species	Habitat
Cupressaceae	*Cupressus montana**	rocky slopes and arroyos, eastern escarpment, La Encantada
Pinaceae	*Pinus coulteri*	N of C. Venado Blanco and W of Arroyo Santa
Garryaceae	*Garrya grisea*	Eulelia, weathered granite slopes
Rosaceae	*Cercocarpus ledifolius*	single population east of Observatory
Agavaceae	*Agave moranii**	lower eastern escarpment and bajadas
Anacardiaceae	*Rhus kearneyii*	washes, eastern escarpment
Crassulaceae	*Sedum niveum*	rocky places, high eastern rim. Also desert ranges of SE California
Polygonaceae	*Eriogonum hastatum*	sandy areas; also S. Juárez
Compositae	*Haplopappus wigginsii**	high meadows, sandy gravelly flats
	*H. martirensis**	weathered granite, crevices, ridges
	*H. pulvinatus**	high eastern cliffs, very rare--Picacho del Diablo and Cerro Observatorio
	*Heterotheca martirensis**	rock outcrops, eastern rim
	*Senecio martinensis**	margins of meadows, in sandy flats and rocky slopes
	Sphaeromeria martirensis	eastern rim, frequent
	*Stephenomeria monocephala**	high eastern rim
Brassicaceae	*Draba corrugata**	gravelly, rocky slopes in pine forest
	Lesquerella peninsularis	sandy meadows
Labiatae	*Hedeoma martirense**	high eastern rim
Malvaceae	*Sphaeralcea martirense**	high eastern rim
Rubiaceae	*Galium wigginsii**	granite boulders
	*G. diabloense**	sandy arroyos and rocky places on Picacho del Diablo
Scrophulariaceae	*Mimulus exiguus*	wet sand, also S. Juárez, San Bernardino Mountains
	M. purpureus pauxillus	meadows and arroyos
	*Ophiocephalus angustifolius**	meadows
Leguminosae	*Astragalus gruinus*	sandy soils, edge of meadows (waifs down to coast)
	Astragalus circumdatus	open, sandy places, also Sierra Juárez
	*Trifolium wigginsii**	high meadows, moist, open sandy places

Table 7. Vegetation changes in Vallecitos exlosures and unfenced controls, 1989-1993. Cover (%) and biomass (g m^2) samples were taken in September of each year (M. G. Barbour, unpublished data).

Year	Exclosure Cover	Control Cover	Exclosure Biomass	Control Biomass
1989	31.7	25.9	36.3	30.0
1990	27.2	17.5	35.4	22.7
1991	79.5	47.0	482.0	102.8
1992	94.0	90.5	625.5	462.5
1993	84.7	85.2	700.0	635.0

Tabla 8. Instituciones involucradas en la investigación o el manejo de la Sierra de San Pedro Mártir.

Asociación Ganadera de San Telmo

Centro de Investigación Científica y de Educaciøn Superior de Ensenada (CICESE)

Colegio de la Frontera Norte (COLEF)

Comisión Nacional del Agua

Comité para el Desarollo Económico de San Quintín (CODEREQ)

Consejo de los Peces del Desierto

Instituto del Borrego Cimarrón

Instituto Nacional de Antropología e Historia (INAH)

Instituto Nacional de Investigaciones Forestales y Agropecuarias (INIFAP)

Patronato Pro-Bosque

Secretaría de Asentamientos Humanos y Obras Públicas del Estado de Baja California (SAHOPE)

Secretaría de Agricultura y Recursos Hidráulicos (SARH)

Secretaría de Fomento Agropecuario del Estado de Baja California

Secretaría de Desarollo Económico del Estado de Baja California

Secretaría de Desarollo Social (SEDESOL)

Universidad de California (Davis, Riverside)

Universidad Estatal de California (Fullerton, San Diego)

Universidad Autónoma de Baja California
- Escuela de Ciéncias Biológicas (Ensenada)
- Instituto de Investigaciones Sociales (Mexicali)
- Taller de Exploración (Ensenada)

Universidad Nacional Autónoma de México (UNAM)
- Observatorio Astronómico Nacional

Fig. 1. Northwestern Baja California, the Sierra San Pedro Mártir (inset), and local place names used in text.

Fig. 2. The Sierra San Pedro Mártir, place names, and study sites. Range gauge stations: A = west slope, 1500 m; B = west slope, 2000 m; C = west plateau, 2500 M; D = east plateau, 2400 m; E = north plateau, 2350 m; F = central plateau, 2200 m. Lysimeter and exclosure sites: LF = lower forest; UP = upper forest; V = Vallecitos. Tree-ring fire chronology sites: 1 = Sierra Corona; 2 = Corona Arriba; 3 = Los Pinos; 4 = Vallecitos; 5 = La Tasajera; 6 = Cerro Botella Azul; 7 = N La Grulla; 8 = S La Grulla; 9 = Pyramid; 10 = Cerro Venado Blanco.

Fig. 3. Conifer forests of the Sierra San Pedro Mártir.

Fig. 4. Fire perimeters for: (A) 1925-41. (B) 1942-55. (C) 1956-71. (D) 1972-91 and (E) the stand mosaic in 1991.

Fig. 5. Proposed core, buffer, and transition zones for the Sierra San Pedro Mártir biosphere reserve.

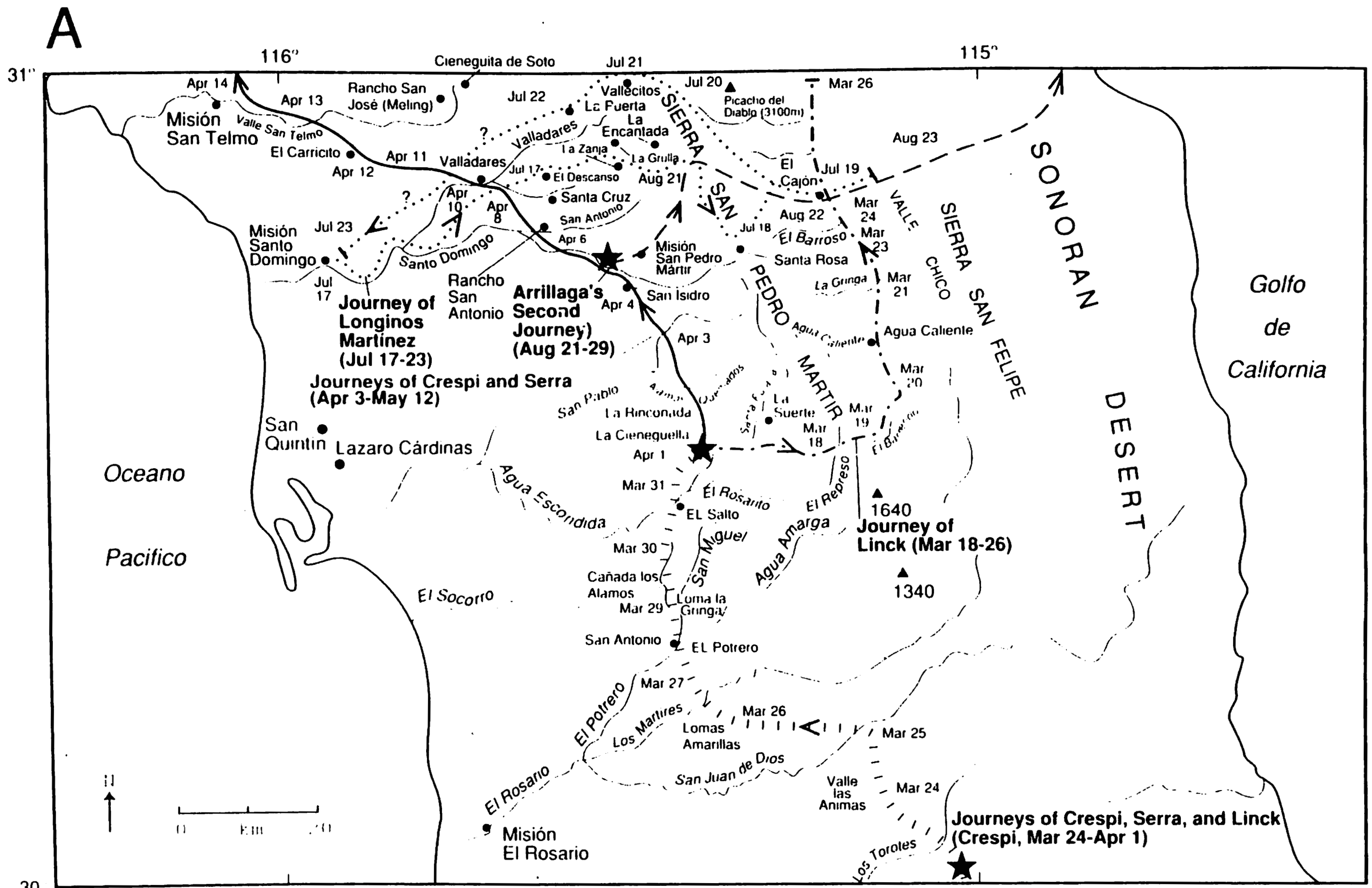
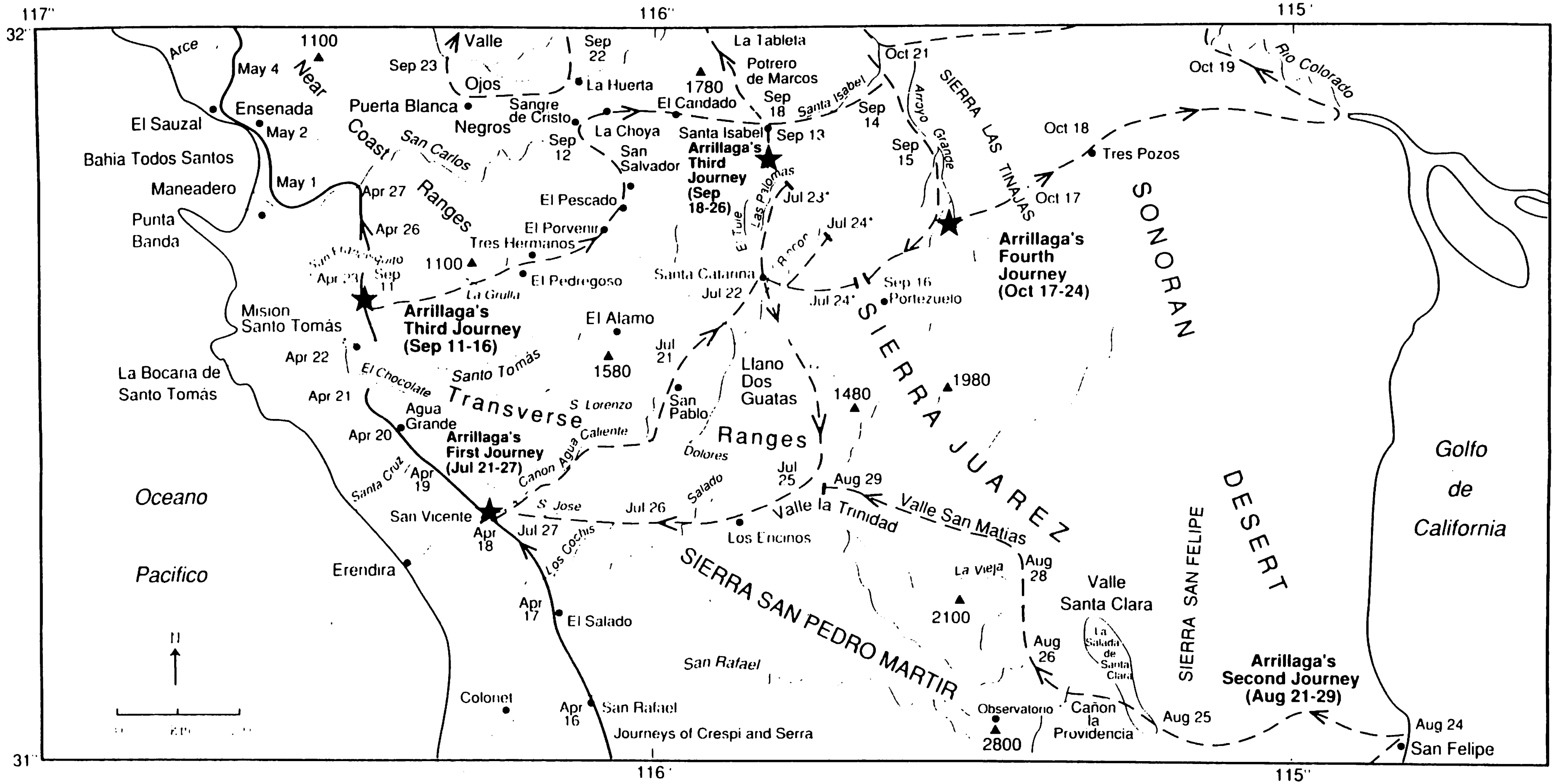

A
116°
115°
31°
30
Cieneguita de Soto
Jul 21
Rancho San José (Meling)
Vallecitos
La Fuerta
La Encantada
Jul 20
Picacho del Diablo (3100m)
Mar 26
Apr 14
Apr 13
Misión San Telmo
Valle San Telmo
El Carricito
Apr 12
Apr 11
Valladares
Jul 22
Aug 23
SIERRA SAN PEDRO MARTIR
El Cajón
Jul 19
SONORAN DESERT
Misión Santo Domingo
Jul 23
Jul 17
Santo Domingo
El Descanso
Santa Cruz
San Antonio
Apr 6
Aug 21
Aug 22
Jul 18
El Barroso
Mar 24
Mar 23
VALLE CHICO
SIERRA SAN FELIPE
Misión San Pedro Mártir
Santa Rosa
La Gringa
Mar 21
Rancho San Antonio
San Isidro
Apr 4
Journey of Longinos Martinez (Jul 17-23)
Arrillaga's Second Journey) (Aug 21-29)
Apr 3
Agua Caliente
Mar 20
Golfo de California
Journeys of Crespi and Serra (Apr 3-May 12)
San Pablo
La Rinconada
La Cienequella
Apr 1
La Suerte
Mar 18
Mar 19
El Barroso
San Quintin
Lazaro Cárdinas
Oceano Pacifico
Agua Escondida
Mar 31
El Rosarito
El Salto
El Represo
Agua Amarga
1640
Journey of Linck (Mar 18-26)
1340
Mar 30
San Miguel
Cañada los Alamos
Loma la Gringa
Mar 29
El Socorro
San Antonio
EL Potrero
Mar 27
El Potrero
Los Martires
Lomas Amarillas
Mar 26
Mar 25
San Juan de Dios
El Rosario
Valle las Animas
Mar 24
Misión El Rosario
Los Torotes
Journeys of Crespi, Serra, and Linck (Crespi, Mar 24-Apr 1)
N
0 Km 20
116
115°

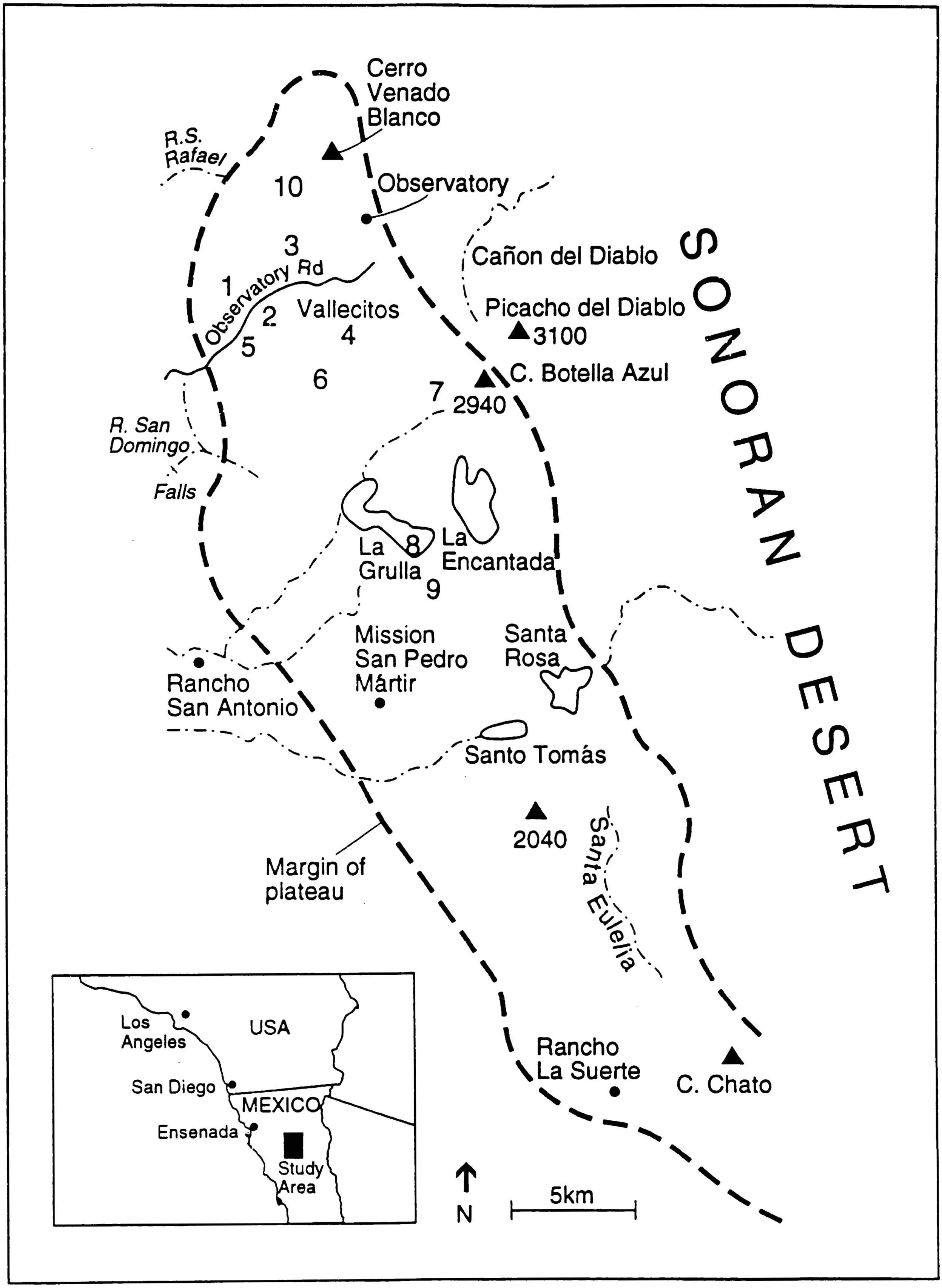
FIGURE 1-A

B



117°
116°
115°
32°
31°
Arce
May 4
Near
Coast
Ranges
1100
Valle
Ojos
Negros
Sep 23
Sep 22
La Huerta
1780
La Tableta
Potrero de Marcos
Oct 21
SIERRA LAS TINAJAS
Arroyo Grande
Oct 19
Rio Colorado
El Sauzal
Ensenada
May 2
Bahia Todos Santos
Maneadero
May 1
Punta Banda
Puerta Blanca
Sangre de Cristo
Sep 12
La Choya
San Salvador
El Candado
Sep 18
Santa Isabel
Sep 13
Sep 14
Sep 15
Oct 18
Tres Pozos
Oct 17
San Carlos
Apr 27
Apr 26
El Pescado
El Porvenir
Tres Hermanos
1100
El Pedregoso
Arrillaga's Third Journey (Sep 18-26)
Las Palomas
El Tule
Jul 23
Jul 24
Santa Catarina
Jul 22
Jul 24
Sep 16
Portezuelo
Arrillaga's Fourth Journey (Oct 17-24)
SONORAN
DESERT
Apr 23
Sep 11
La Grulla
Mision Santo Tomás
Arrillaga's Third Journey (Sep 11-16)
El Alamo
Jul 21
Llano Dos Guatas
SIERRA JUAREZ
1980
1480
1580
Apr 22
La Bocana de Santo Tomás
Apr 21
El Chocolate
Santo Tomás
Transverse
Ranges
S Lorenzo
San Pablo
Agua Grande
Apr 20
Arrillaga's First Journey (Jul 21-27)
Agua Caliente
Dolores
Jul 25
Aug 29
Valle San Matias
Oceano
Pacifico
Santa Cruz
Apr 19
Canon
San Vicente
Apr 18
S Jose
Jul 26
Salado
Valle la Trinidad
Los Encinos
Jul 27
Los Cochis
Golfo
de
California
SIERRA SAN PEDRO MARTIR
Erendira
La Vieja
Aug 28
Valle Santa Clara
SIERRA SAN FELIPE
2100
Apr 17
El Salado
Aug 26
La Salada de Santa Clara
San Rafael
Arrillaga's Second Journey (Aug 21-29)
Colonet
Apr 16
San Rafael
Journeys of Crespi and Serra
Observatorio
2800
Cañon la Providencia
Aug 25
Aug 24
San Felipe
N

FIGURE 1-B



Cerro
Venado
Blanco
R.S.
Rafael
10
Observatory
3
Observatory Rd
1
2
5
Vallecitos
4
6
Cañon del Diablo
Picacho del Diablo
3100
C. Botella Azul
7
2940
SONORAN DESERT
R. San
Domingo
Falls
La
Grulla
8
La
Encantada
9
Mission
San Pedro
Mártir
Santa
Rosa
Rancho
San Antonio
Santo Tomás
2040
Santa Eulelia
Margin of
plateau
Rancho
La Suerte
C. Chato
Los
Angeles
USA
San Diego
MEXICO
Ensenada
Study
Area
N
5km

FIGURE 2

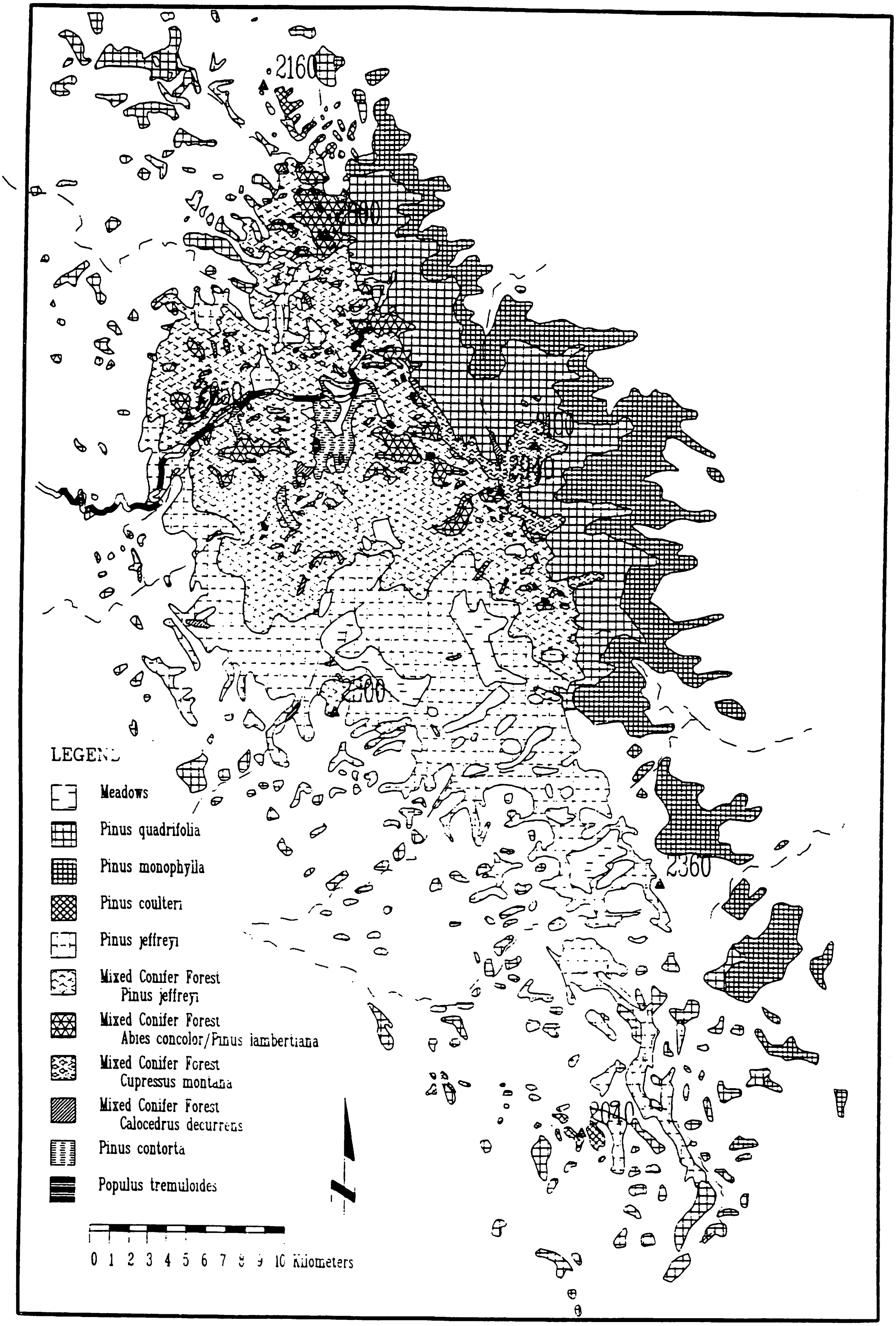

2160
2360
LEGEND
Meadows
Pinus quadrifolia
Pinus monophyila
Pinus coulteri
Pinus jeffreyi
Mixed Conifer Forest
Pinus jeffreyi
Mixed Conifer Forest
Abies concolor/Pinus lambertiana
Mixed Conifer Forest
Cupressus montana
Mixed Conifer Forest
Calocedrus decurrens
Pinus contorta
Populus tremuloides
0 1 2 3 4 5 6 7 8 9 10 Kilometers

FIGURE 3

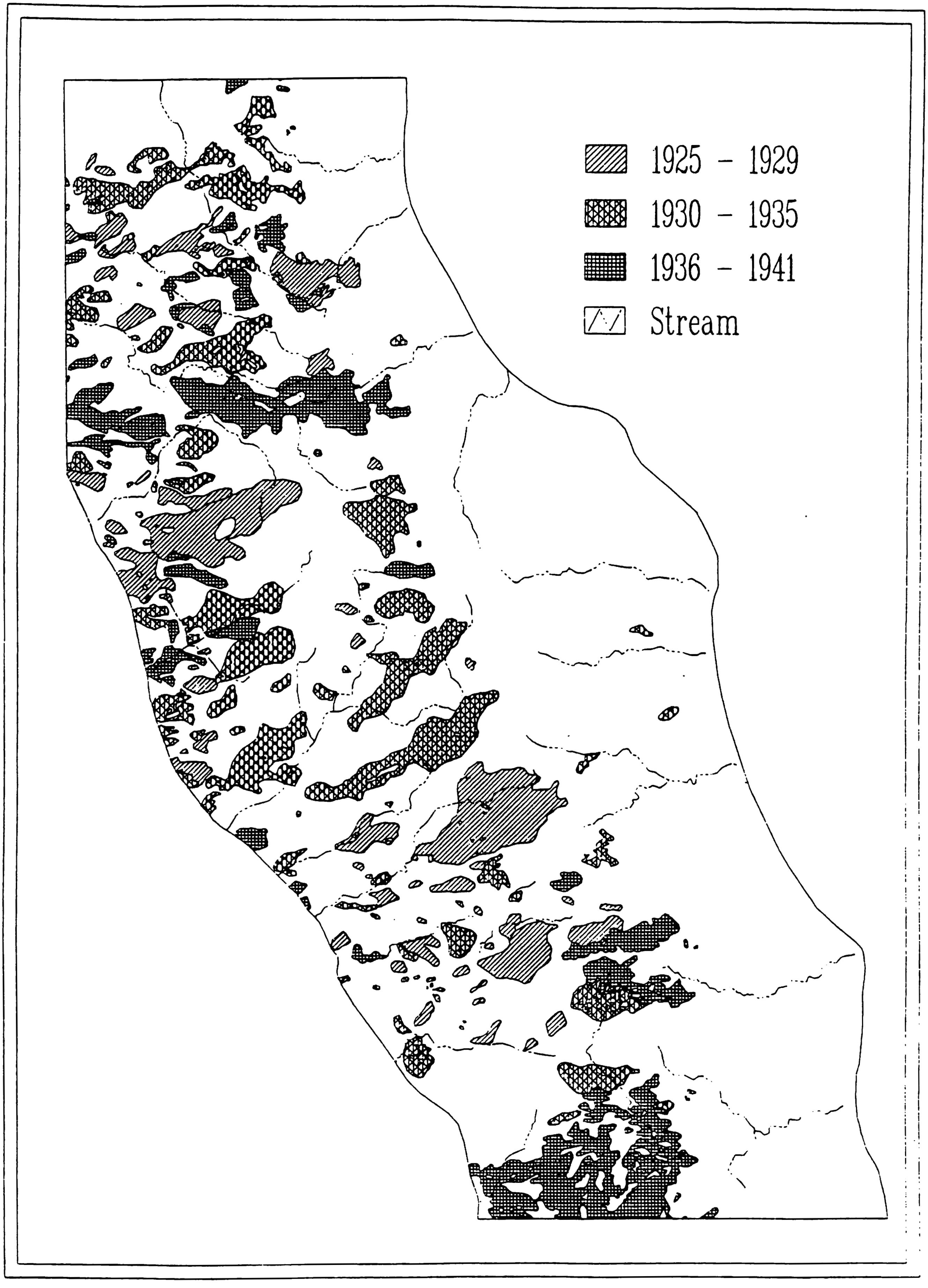


FIGURE 4-A

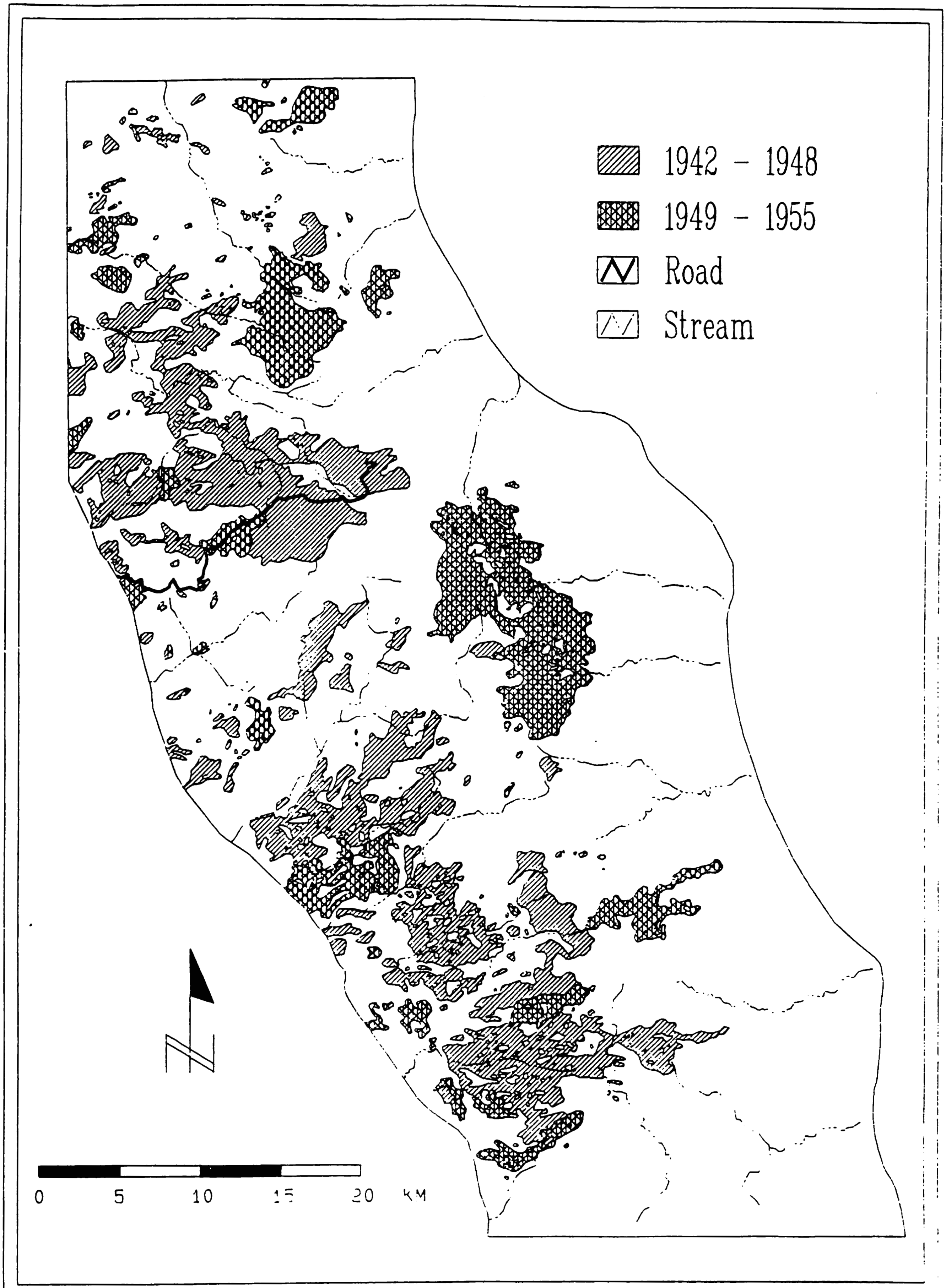


FIGURE 4-B

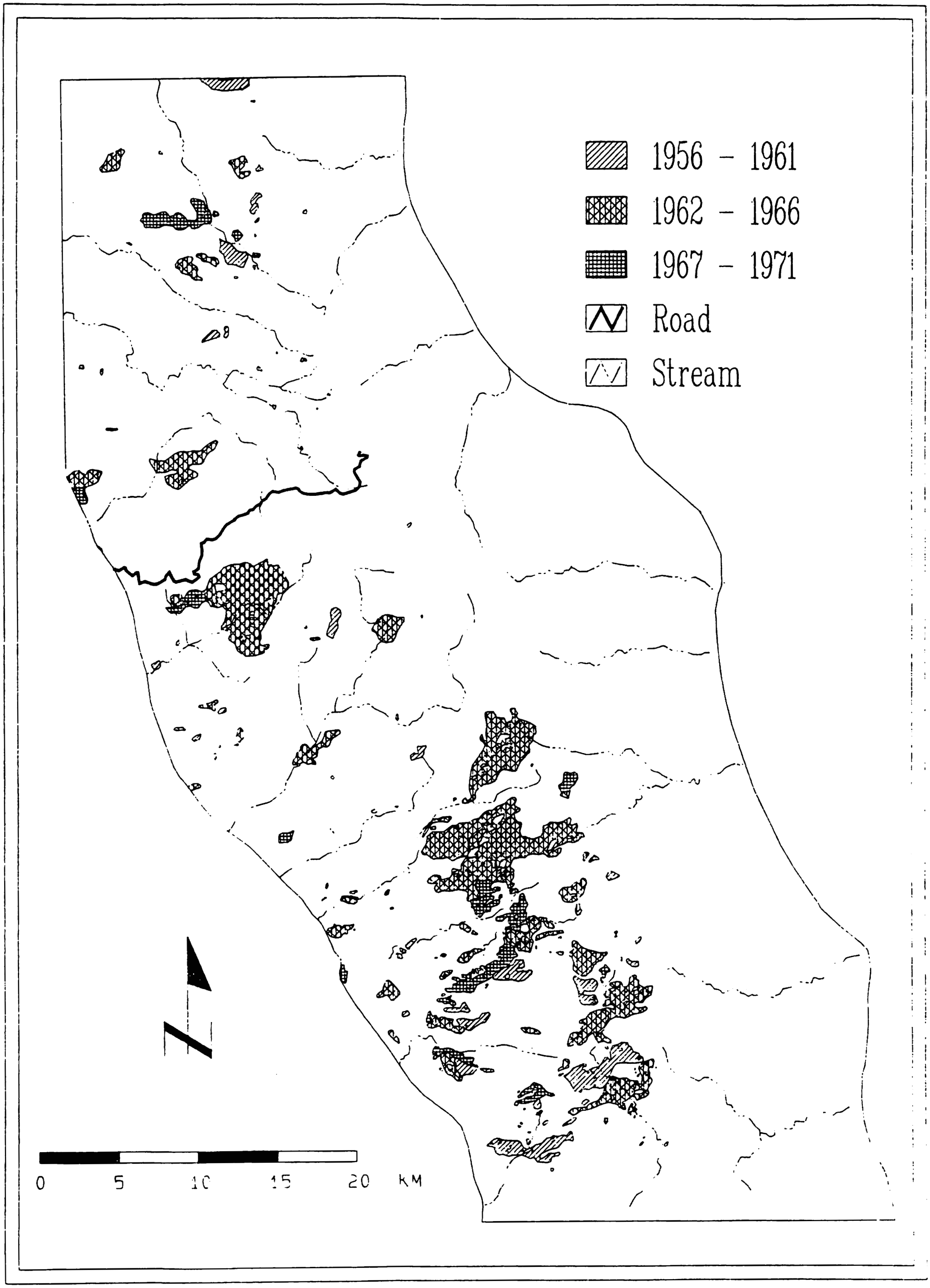


FIGURE 4-C

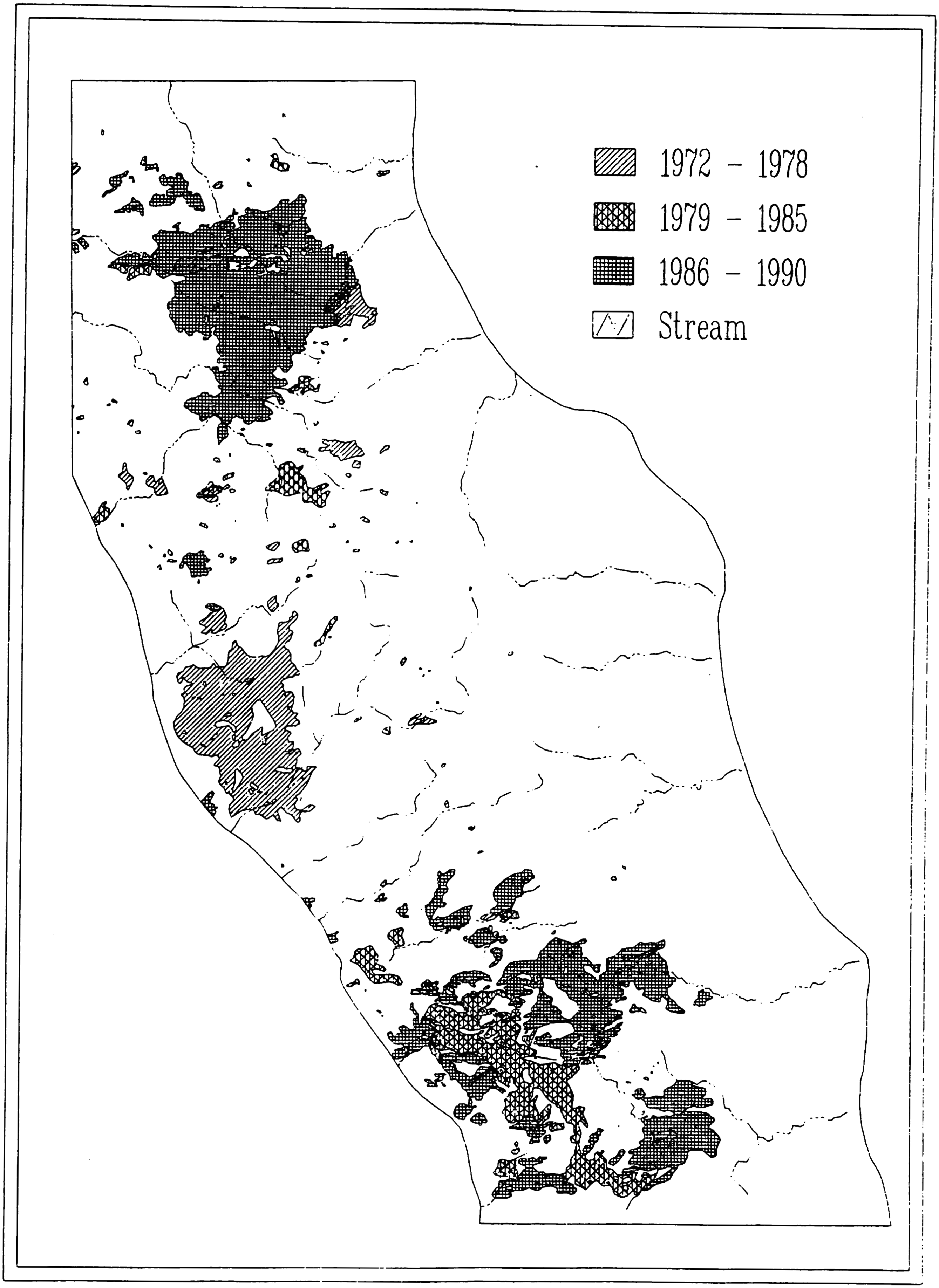


FIGURE 4-D

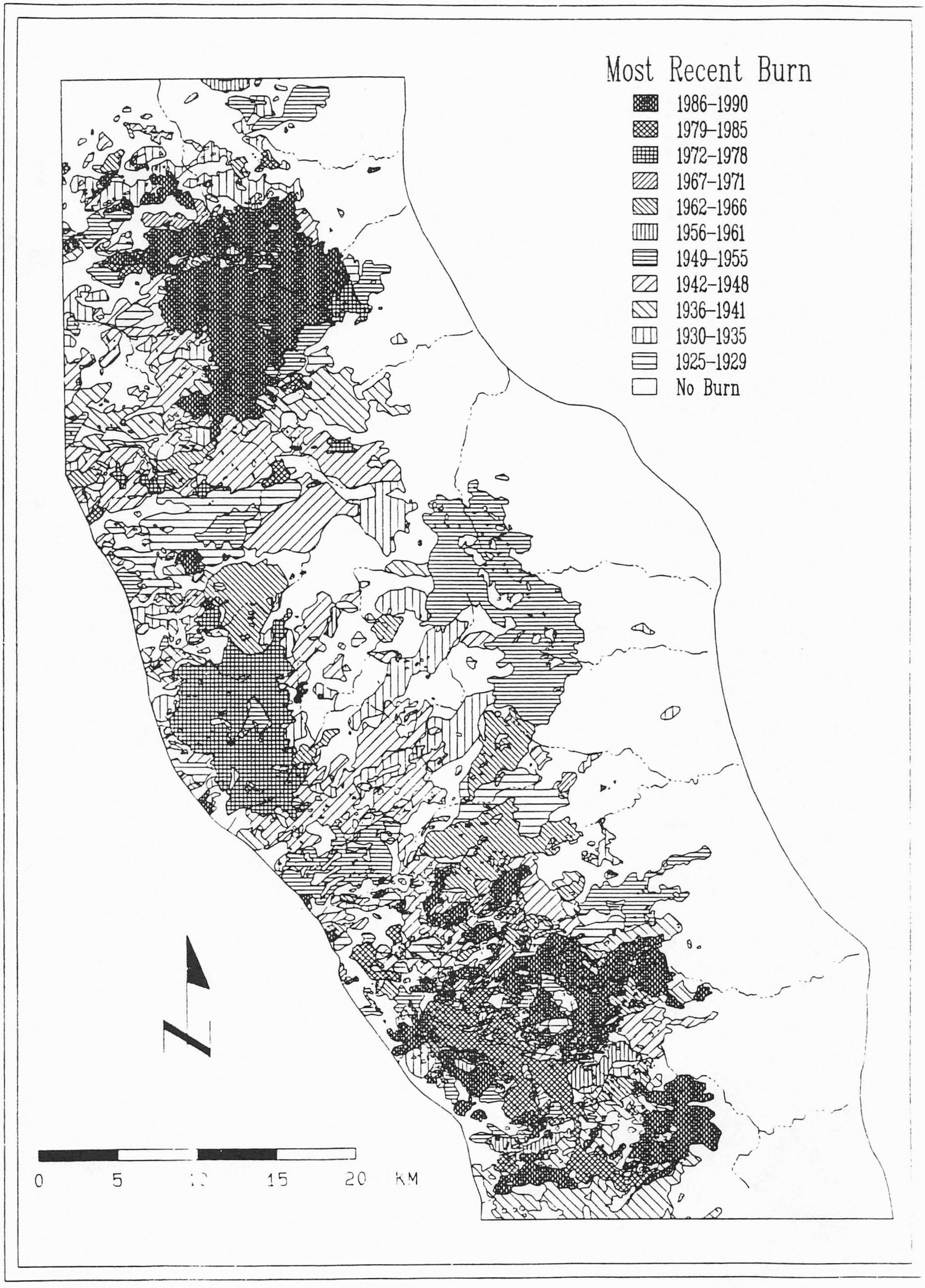

Most Recent Burn
1986-1990
1979-1985
1972-1978
1967-1971
1962-1966
1956-1961
1949-1955
1942-1948
1936-1941
1930-1935
1925-1929
No Burn
0
5
15
20
KM

FIGURE 4-E

FIGURE 5

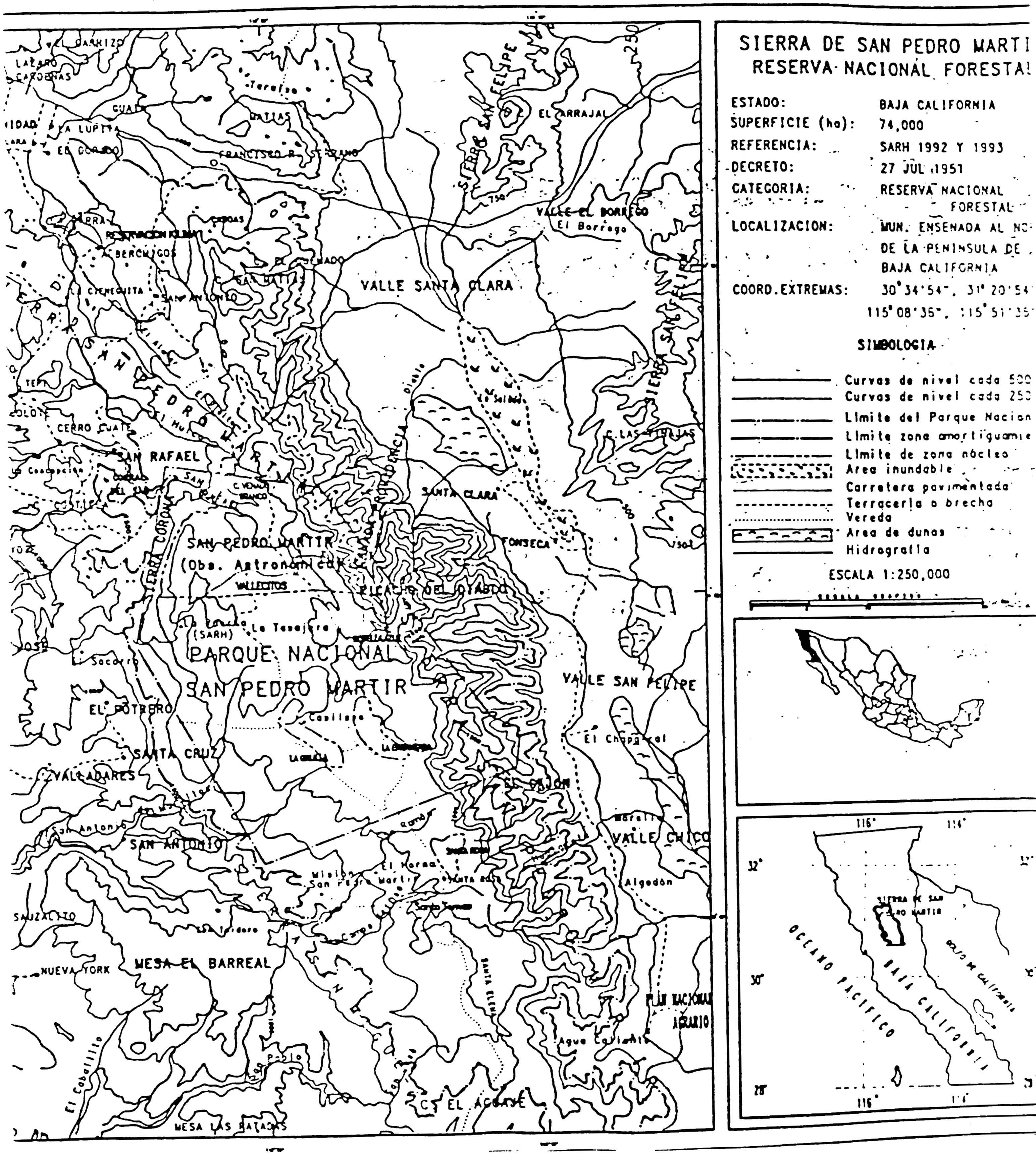

SIERRA DE SAN PEDRO MARTI
RESERVA NACIONAL FORESTAL
ESTADO: BAJA CALIFORNIA
SUPERFICIE (ha): 74,000
REFERENCIA: SARH 1992 Y 1993
DECRETO: 27 JUL 1951
CATEGORIA: RESERVA NACIONAL FORESTAL
LOCALIZACION: MUN. ENSENADA AL NO DE LA PENINSULA DE BAJA CALIFORNIA
COORD. EXTREMAS:
SIMBOLOGIA
Curvas de nivel cada 500
Curvas de nivel cada 250
Limite del Parque Nacion
Limite zona amortiguamie
Limite de zona núcleo
Area inundable
Carretera pavimentada
Terracería o brecha
Vereda
Area de dunas
Hidrografía
ESCALA 1:250,000
VALLE SANTA CLARA
SANTA CLARA
SAN RAFAEL
CERRO CUATE
SAN PEDRO MARTIR
(Obs. Astronomica)
PICACHO DEL DIABLO
PARQUE NACIONAL
SAN PEDRO MARTIR
VALLE SAN FELIPE
EL POTRERO
SANTA CRUZ
SAN ANTONIO
MESA EL BARREAL
NUEVA YORK
VALLE CHICO
EL CAJON
FONSECA
VALLE EL BORREGO
El Borrego
EL ARRAJAL
FRANCISCO R. SERRANO
El Chaparral
Algodón
Agua Caliente
MESA LAS BATATAS
C. EL AGAVE
SAUZALITO
OCEANO PACIFICO
BAJA CALIFORNIA

FIGURE 5

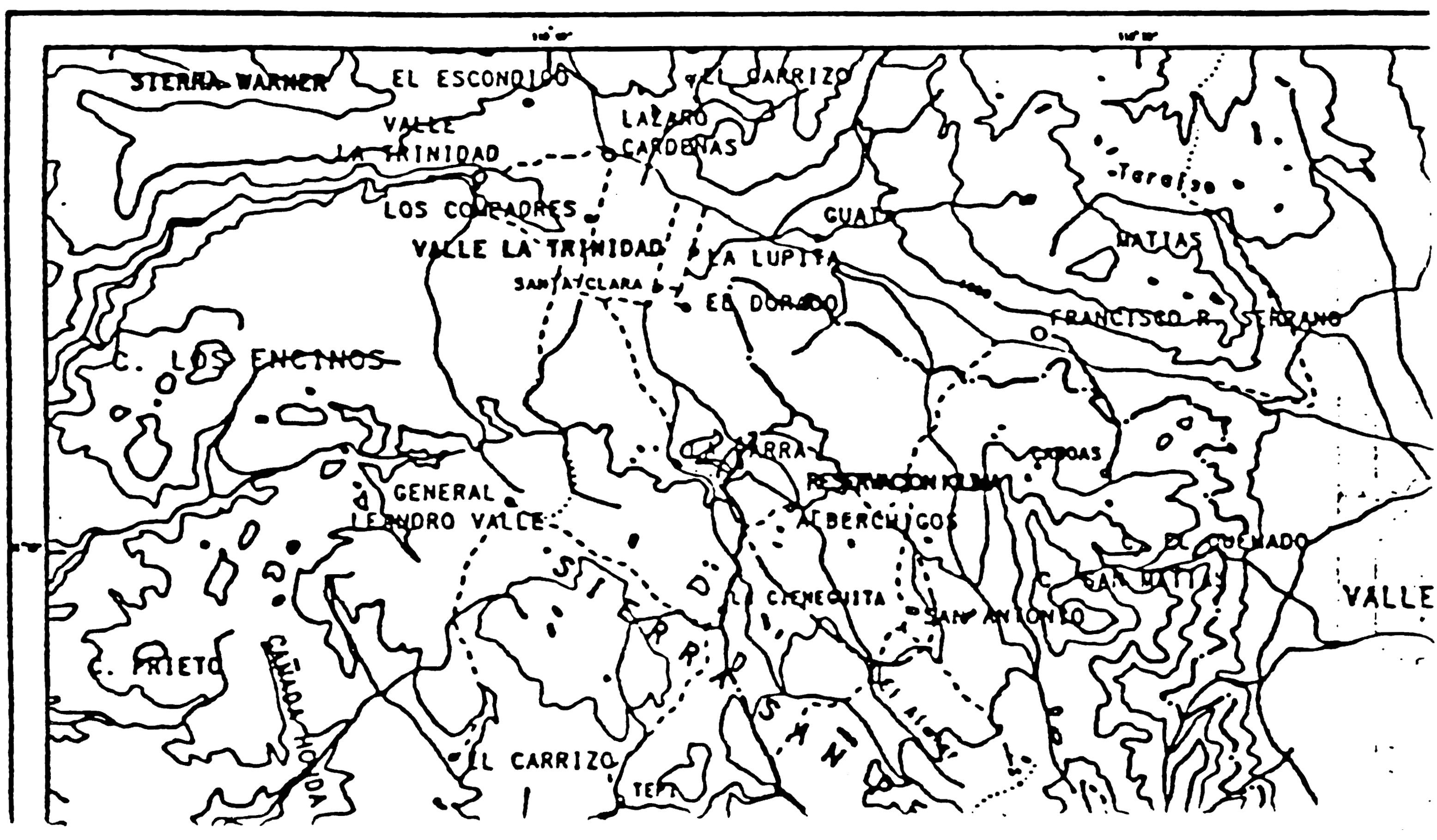
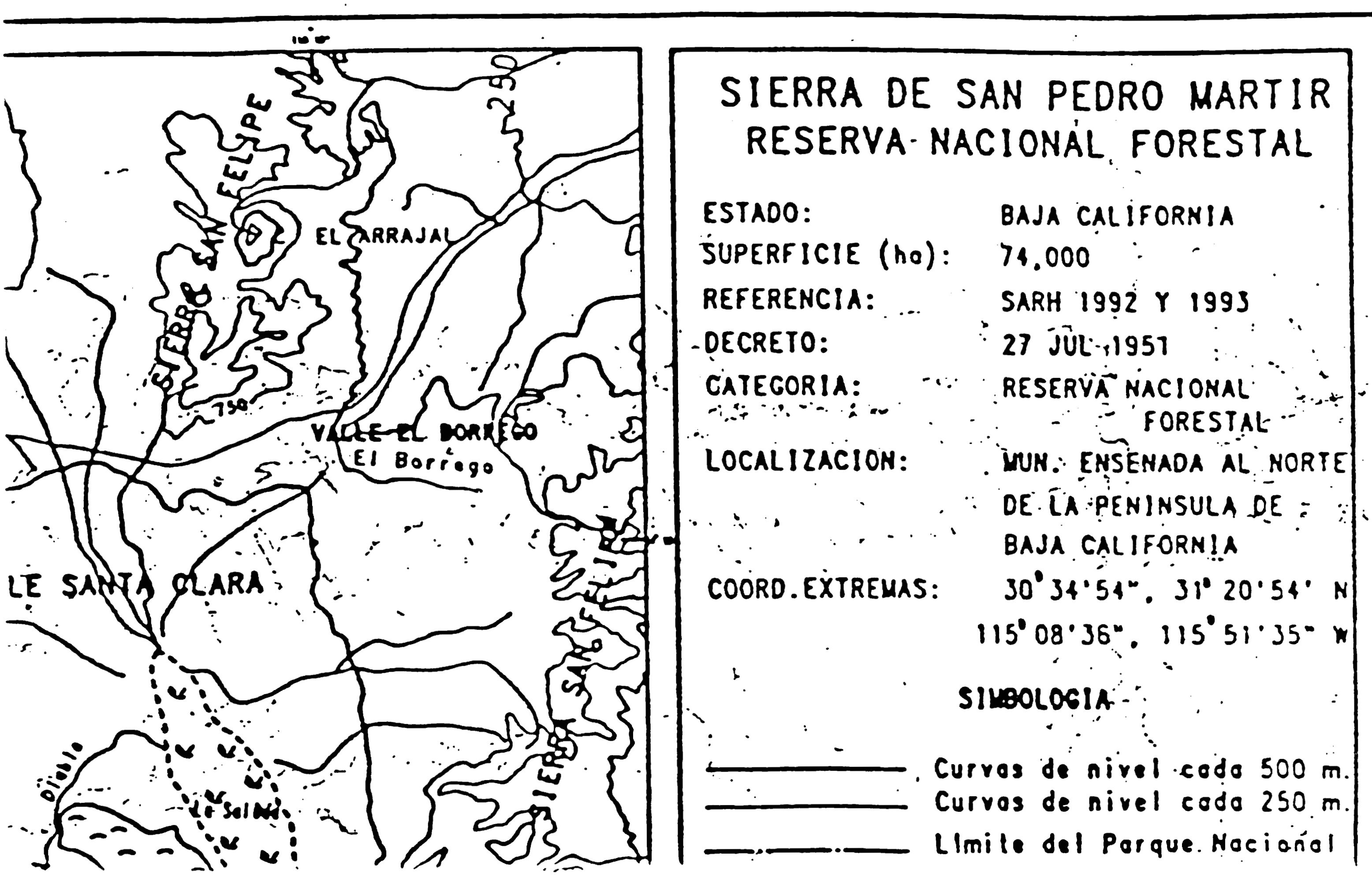
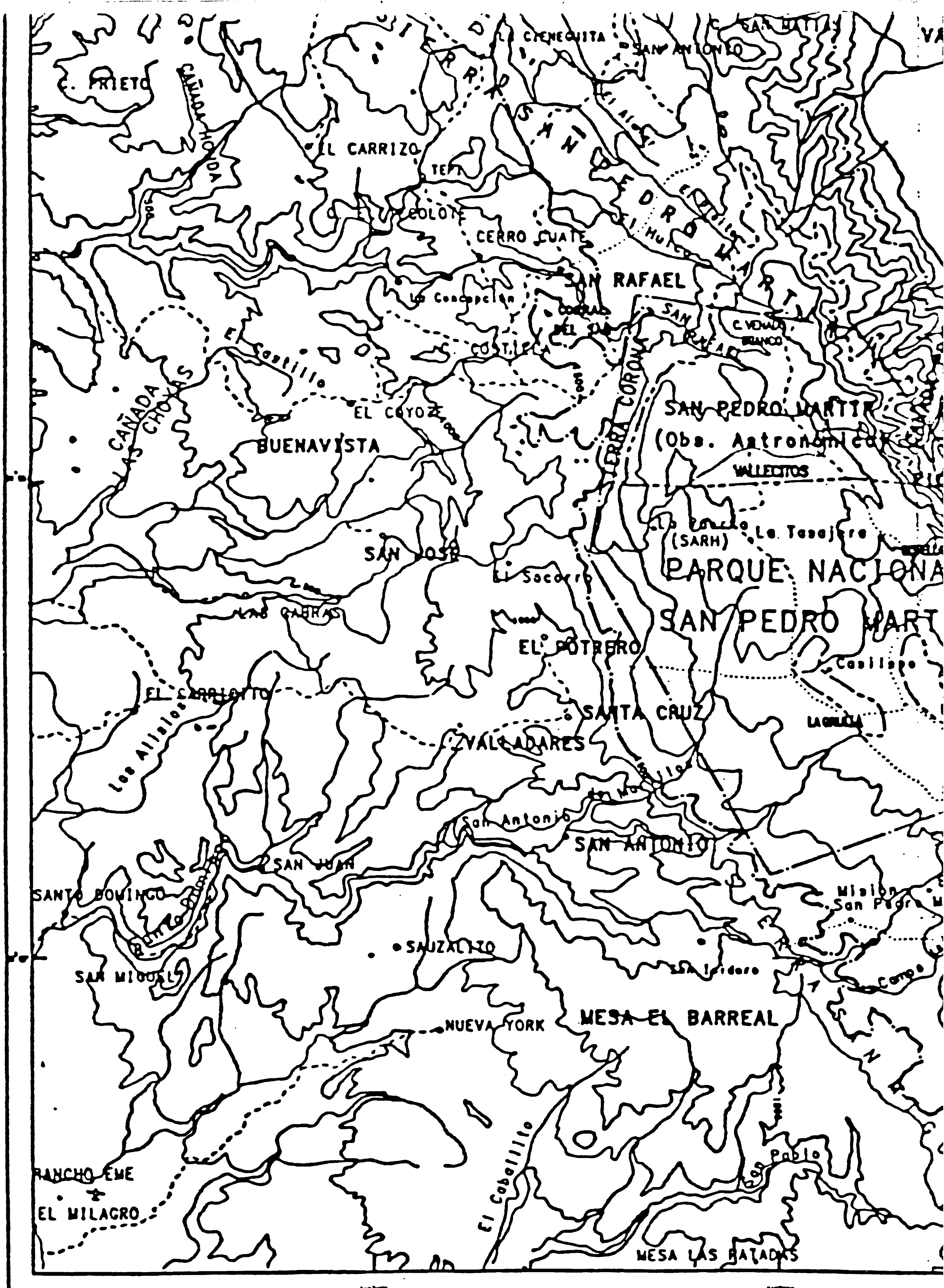

SIERRA WARNER
EL ESCONDIDO
EL CARRIZO
VALLE
LA TRINIDAD
LAZARO
CARDENAS
LOS COMPADRES
VALLE LA TRINIDAD
LA LUPITA
SANTA CLARA
EL DORADO
MATIAS
FRANCISCO R. SERRANO
C. LOS ENCINOS
GENERAL
LEANDRO VALLE
ALBERCHIGOS
EL QUEMADO
C. SAN MATIAS
LA CIENEGUITA
SAN ANTONIO
VALLE
C. PRIETO
EL CARRIZO

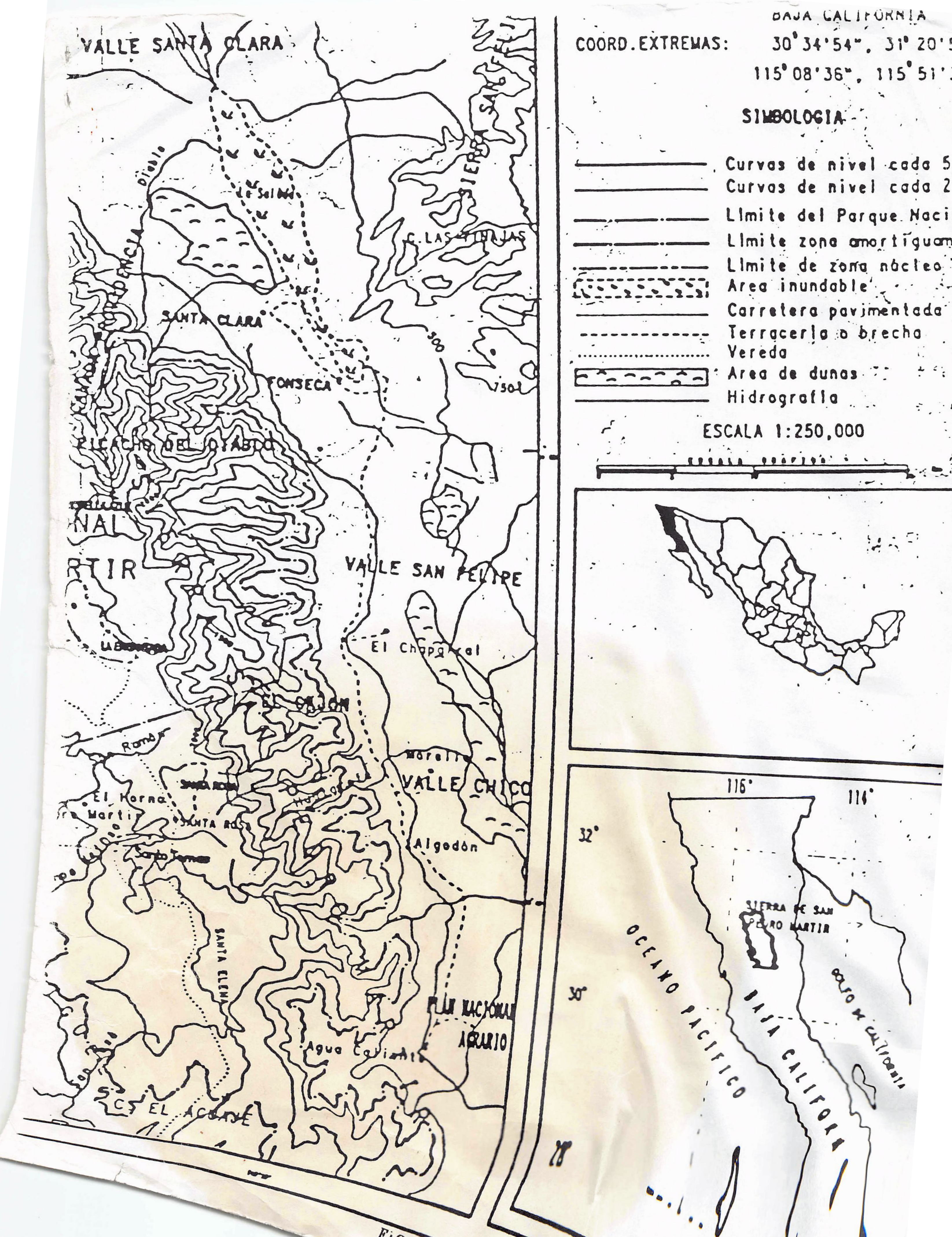
FIGURE 5


SIERRA DE SAN PEDRO MARTIR
RESERVA NACIONAL FORESTAL
ESTADO: BAJA CALIFORNIA
SUPERFICIE (ha): 74,000
REFERENCIA: SARH 1992 Y 1993
DECRETO: 27 JUL 1951
CATEGORIA: RESERVA NACIONAL FORESTAL
LOCALIZACION: MUN. ENSENADA AL NORTE DE LA PENINSULA DE BAJA CALIFORNIA
COORD. EXTREMAS: 30°34'54", 31°20'54' N
115°08'36", 115°51'35" W
SIMBOLOGIA
Curvas de nivel cada 500 m.
Curvas de nivel cada 250 m.
Limite del Parque Nacional
SIERRA SAN FELIPE
EL ARRAJAL
250
750
VALLE EL BORREGO
El Borrego
LE SANTA CLARA
Diablo



EL CARRIZO
CERRO CUATE
SAN RAFAEL
La Concepcion
El Castillo
EL COYOTE
BUENAVISTA
CAÑADA LAS CHOYAS
CAÑADA HONDA
SAN PEDRO MARTIR
(Obs. Astronomico)
VALLECITOS
La Tasajera
(SARH)
PARQUE NACIONAL
SAN JOSE
El Socorro
LAS CABRAS
EL POTRERO
SANTA CRUZ
VALLADARES
Los Alisitos
San Antonio
SAN ANTONIO
SAN JUAN
SAUZALITO
MESA EL BARREAL
NUEVA YORK
RANCHO EME
EL MILAGRO
El Caballillo

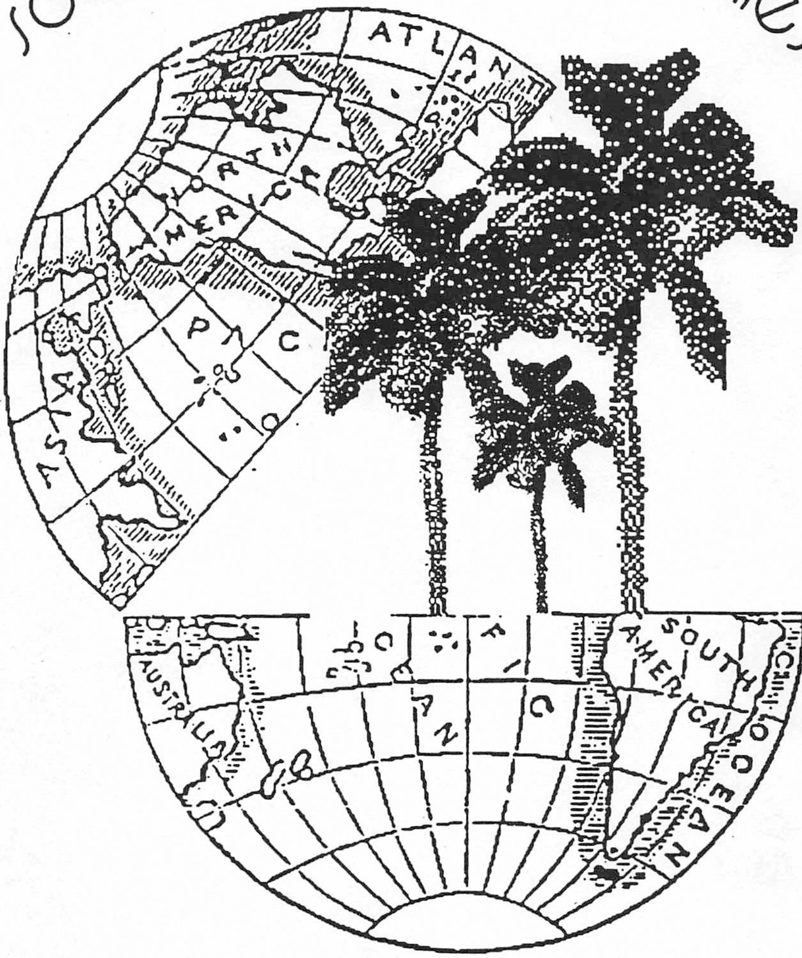
FIGURE 5



BAJA CALIFORNIA
COORD. EXTREMAS: 30°34'54", 31°20'5
115°08'36", 115°51'
SIMBOLOGIA
Curvas de nivel cada 5
Curvas de nivel cada 2
Limite del Parque Naci
Limite zona amortiguam
Limite de zona núcleo
Area inundable
Carretera pavimentada
Terracería o brecha
Vereda
Area de dunas
Hidrografía
ESCALA 1:250,000
VALLE SANTA CLARA
SIERRA SAN FELIPE
C. LAS TINAJAS
SANTA CLARA
FONSECA
PICACHO DEL DIABLO
VALLE SAN FELIPE
El Chaparral
EL CAJON
Morelia
VALLE CHICO
El Horno
Algodón
SANTA ROSA
SANTA ELENA
PLAN NACIONAL AGRARIO
Agua Caliente
EL ACEITE
116°
32°
30°
28°
SIERRA DE SAN PEDRO MARTIR
OCEANO PACIFICO
BAJA CALIFORNIA
GOLFO DE CALIFORNIA

FIGURE 5

Proyecto sobre Areas Naturales Protegidas



El potencial de la Sierra de San Pedro Mártir como una Reserva de la Biosfera.

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México, 1994